THE

CHEMISTRY OF COMMON LIFE

FÜHRT DIE CHEMIE IN DIESEM AUGENBLICK IHR SCEPTER ÜBER ALLE ANDERE NATURWISSENSCHAFTEN.—*Moleschott.*

TILL BY EXPERIENCE TAUGHT THE MIND SHALL LEARN
THAT, NOT TO KNOW AT LARGE OF THINGS REMOTE
FROM USE, OBSCURE AND SUBTLE, BUT TO KNOW
THAT WHICH BEFORE US LIES IN DAILY LIFE,
IS THE PRIME WISDOM.—*Milton.*

ALL THE FORMS ARE FUGITIVE,
BUT THE SUBSTANCES SURVIVE.—*Emerson.*

THE

CHEMISTRY OF COMMON LIFE

BY THE LATE

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A NEW EDITION

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EDITOR'S PREFACE.

TWENTY-FIVE years ago, when 'The Chemistry of Common Life' first appeared, an acquaintance with the advancing science of the day was the almost exclusive possession of a select class of professional persons. The English chemical literature of that time was exceedingly meagre; while, save in London and a few great cities, instruction, by means of lectures and laboratory work, was wellnigh unknown. Even educated persons had no notion of the real scope and functions of chemistry, beyond a hazy impression that medical practitioners had mastered its theory, and druggists its practice. Professor Johnston's popular exposition of the main conclusions touching the daily life of man first revealed to the public a new world of interest. His book was most attractive in style, most interesting and comprehensive as to subject-matter, and most exact. His simple and familiar method of introducing the facts and reasonings of chemistry to the general reader was itself a novel and charming experiment, which at once attracted a crowd of admirers, and which in the lapse of time has lost none

of its fascination. In the number and variety of striking illustrations, in the simplicity of its style, and in the closeness and cogency of its arguments, Professor Johnston's 'Chemistry of Common Life' has as yet found no equal among the many books of a similar character which its success originated, and it steadily maintains its pre-eminence in the popular scientific literature of the day.

In preparing this Edition for the press, my first aim has been to respect the method, the style, and the matter of Professor Johnston's work. Thus only such corrections and such omissions have been made as the progress of science demanded, while the additions which I have introduced are confined to subjects congenial to the original plan of the book, and are such as will, I hope, prove useful in filling up a few blanks in the sketch. I have, indeed, ventured to write one entirely new chapter, treating of some of "The Colours we Admire," but the subject is one which, I am sure, would have specially attracted the attention of Professor Johnston had his life been prolonged but a year or two; for he has discussed with considerable fulness the somewhat similar subject of "The Odours we Enjoy," pointing out the peculiar interest attached to the artificial reproduction of natural perfumes. The analogous formation in the laboratory of natural colouring matters, one of the latest triumphs of constructive chemistry, is of still greater importance; while the further light which has been recently thrown upon the nature and functions of certain animal and vegetable pigments,—for instance, leaf-green and blood-red,—warrants the insertion of a few paragraphs descriptive of a select series of these curious compounds. It would

be impracticable to specify the many lesser additions which have been made to the volume, but their aggregate number may be gauged by the numerous fresh references which have been inserted in the new Index. It would be equally impracticable to cite authority for each new statement made or figure given; the space which would have been thus occupied has been, I hope, more profitably employed. A good many of the new analyses (such as those of roots) are either wholly or partly my own; in fact, I have gathered these and other new data not only from my published works, but also from original materials which I have accumulated with a view to other literary or professional uses.

In some few instances I have left unchanged in the text statistics, calculations, and explanations which seemed to be of somewhat doubtful authority, but which I have been unable to replace by more satisfactory figures and arguments: sometimes they have been retained on account of their possessing a measure of historical interest. I trust that actual errors of statement will prove of rare occurrence, though, in a work of such wide range, I cannot hope to have altogether avoided them.

It is a happy circumstance that I had the opportunity of consulting Professor Johnston's private and corrected copy of the 'Chemistry of Common Life.' He had already, in two or three years, gleaned very many fresh details for his volume, so that I was able not only to incorporate with my revision some really valuable matter which he had gathered, but to learn the kind of additions which he contemplated. I am bound, how-

ever, to confess that the book would have been doubled or trebled in size had I not exercised a somewhat severe judgment in adding fresh matter. As it is, the work, though appearing in a single volume, contains much more letterpress than the previous issues—thanks to a smaller type, closer printing, larger pages, and the omission of a few woodcuts of chemical apparatus. These illustrations were, in fact, no longer needed, since the appearance of cheap manuals of experimental chemistry.

I sincerely trust that my revision of Professor Johnston's 'Chemistry of Common Life' will enhance the usefulness of an interesting book, which has attained, as it deserved, an extensive popularity.

A. H. CHURCH.

February 1879.

AUTHOR'S INTRODUCTION.

THE common life of man is full of wonders, Chemical and Physiological. Most of us pass through this life without seeing or being sensible of them, though every day our existence and our comforts ought to recall them to our minds. One main cause of this is, that our schools tell us nothing about them—do not teach those parts of modern learning which would fit us for seeing them. What most concerns the things that daily occupy our attention and cares, are in early life almost sedulously kept from our knowledge. Those who would learn anything regarding them, must subsequently teach themselves through the help of the press: hence the necessity for a Popular Chemical Literature.

It is with a view to meet this want of the Public, and at the same time to supply a Manual for the Schools, that the present Work has been projected. It treats, in what appears to be their natural order, of THE AIR WE BREATHE and THE WATER WE DRINK, in their relations to human life and health—THE SOIL WE CULTIVATE and THE PLANT WE REAR, as the sources from which the chief sustenance of all life is obtained—THE BREAD WE EAT and THE BEEF WE COOK, as the representatives of the two grand divisions of human food—THE BEVERAGES WE INFUSE, from which so much of the comfort of modern life, both savage and civilised, is derived—THE SWEETS

WE EXTRACT, the history of which presents so striking an illustration of the economical value of chemical science —THE LIQUORS WE FERMENT, so different from the sweets in their action on the system, and yet so closely connected with them in chemical history—THE NARCOTICS WE INDULGE IN, as presenting us with an aspect of the human constitution which, both chemically and physiologically, is more mysterious and wonderful than any other we are yet acquainted with—THE ODOURS WE ENJOY and THE SMELLS WE DISLIKE; the former because of the beautiful illustration they present of the recent progress of organic chemistry in its relations to the comforts of common life, and the latter because of their intimate connection with our most important sanitary arrangements—WHAT WE BREATHE FOR and WHY WE DIGEST, as relating to functions of the body at once the most important to life, and the most purely chemical in their nature—THE BODY WE CHERISH, as presenting many striking phenomena, and performing many interesting chemical functions not touched upon in the discussion of the preceding topics—and lastly, the CIRCULATION OF MATTER, as exhibiting in one view the end, purpose, and method of all the changes in the natural body, in organic nature, and in the mineral kingdom, which are connected with and determine the existence of life.

It has been the object of the Author in this Work, to exhibit the present condition of chemical knowledge, and of matured scientific opinion, upon the subjects to which it is devoted. The reader will not be surprised, therefore, should he find in it some things which differ from what is to be found in other popular works already in his hands or on the shelves of his library.

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THE

CHEMISTRY OF COMMON LIFE.

CHAPTER I.

THE AIR WE BREATHE.

Height of the earth's atmosphere; air is one of the elements of the ancients.—Composition of the atmosphere.—Oxygen, preparation and properties of.—Nitrogen, preparation and properties of.—Proportions of these elements in the air; their adaptation in kind and quantity to the existing condition of things.—Uses of the oxygen and nitrogen.—Uses of the carbonic acid; its importance to vegetable life, and deleterious influence upon animal life.—The "Poison Valley" of Java.—Importance of the watery vapour of the air; its constant circulation.—Formation of rain and dew; their many uses.—Accidental constituents of the air; ozone, nitric acid, and ammonia.—Vapours which rise from the surface of the earth, and saline matters from the sea.

THE earth we inhabit is surrounded by an atmosphere of air, the height of which is at least forty-five miles. It may extend much farther, but its outer parts will be excessively attenuated. Some notion of the thickness of this mantle of air which clothes our globe may be gained from the following comparison: a globe of 6 feet in diameter, if surrounded by an atmosphere corresponding to that of the earth, would be covered by a layer of air ½ an inch in depth. The atmosphere presses upon the earth with a weight equal at the level of the sea to nearly 15 lb. on every square inch of surface. As we ascend

high mountains, this weight becomes less; and as we go down into deep mines, it becomes sensibly greater.

We breathe this atmospheric air, and without it we could not live. It floats around the earth in almost perpetual motion; and according to the quickness with which it moves, it produces gentle breezes, swift winds, or terrible tornadoes.

Though very familiar to us, and regarded with little curiosity, this air is yet very wonderful, both in itself and in its uses. Imperfect as the knowledge of the ancients was, they recognised its importance by giving it a place among what they regarded as the four primal elements of nature—fire, air, earth, and water.

Yet, though apparently pure and elementary, it is by no means either a simple or pure substance. It is a mixture of several different kinds of matter, each of which performs a beautiful and appropriate part in relation to animal and vegetable life. Four substances, at least, are known to be always present in it. Two of these, oxygen and nitrogen, form nearly its entire bulk; the two others, carbonic acid and watery vapour, being present only in minute quantities.

Oxygen is a kind of air or gas, which, like the atmosphere itself, is without colour, taste, or smell. It is an element—that is, it has never been decomposed into two different substances. When cooled far below the freezing-point of water, and at the same time, pressed upon by a force equal to 300 atmospheres, it becomes a liquid. A candle burns in it with much greater brilliancy and rapidity than in common air. Animals also breathe in it with an increase of pleasure; but it excites them, quickens their circulation, throws them into a state of fever, and finally kills them, by excess of excitement. They live too rapidly in pure oxygen gas, and burn away in it like the fast-flaring candle.

This gas is easily prepared by mixing 100 grains of the chlorate of potash of the shops with 10 grains of jeweller's rouge or red oxide of iron, and heating the mixture in a flask over a spirit-lamp. The gas is soon given off, and will quickly fill and overflow the flask. It cannot be seen by the eye, or be detected by any of the other senses. Its presence may be readily shown, however, by introducing a lighted taper, or a bit of red-hot charcoal, or of kindled phosphorus, at the end of a wire. The brilliancy of the burning will prove the presence

of the gas; a merely smouldering wick or glowing splint of wood will burst into flame.

Nitrogen is also a kind of air which, like oxygen, is void of colour, taste, and smell; but a lighted candle is instantly extinguished, and animals cease to breathe when introduced into it. It is an element, and has been made by cold and pressure to assume the liquid form. We obtain this gas by putting a bit of phosphorus into a small cup over water, kindling it, and inverting over it a bottle, dipping with its mouth into the water. When the phosphorus has ceased to burn, and the bottle has become cool, it may be corked and removed from the water. If a lighted taper be now introduced into the bottle, it will immediately be extinguished, showing that a gas very unlike oxygen remains. In this process the burning phosphorus removes the oxygen, or most of it, from the air contained in the bottle, and leaves the nitrogen.

Oxygen is one-ninth part *heavier*, and nitrogen one thirty-sixth part *lighter*, than common air.

Carbonic acid is a kind of air which, like oxygen and nitrogen, is void of colour; but, unlike them, possesses a slight odour, and a perceptibly sour taste; and it is, moreover, a compound, not an element, containing two elements—oxygen itself, and carbon. Burning bodies are extinguished, and animals cease to breathe, when introduced into it. It is one-half heavier than common air, and can therefore be poured through the air from one vessel to another. When passed through lime-water,[1] it makes it milky, forming with the dissolved lime an insoluble white powder, which, because it contains carbonic acid, is called *carbonate* of lime, and is the same thing as chalk. It is the escape of this gas which gives their sparkling briskness to fermented liquors, to soda-water, and to the waters of some mineral springs.

Carbonic acid is easily prepared by pouring vinegar upon common soda, or diluted spirit of salt (muriatic acid) upon chalk or limestone. The gas rises in bubbles through the liquid, and, in consequence of its weight, remains in the lower part of the vessel. As it collects it gradually ascends, driving

[1] Lime-water is formed by pouring water upon slaked lime, shaking them well together, and allowing the mixture to settle. The clear liquid contains a portion of the lime in solution, and is therefore called *lime*-water: 600 lb. of water dissolve about 1 lb. of lime.

the common air before it, and at last flows, as water would do, over the edge of the vessel. Its rise may be shown by introducing two lighted tapers, one below the other, when the lower one will be seen to go out, while the upper one is still burning.

By *watery vapour* is meant the steam or vapour, visible or invisible, which ascends from a surface of water when exposed to the air. When water is spilt upon the ground in dry weather, it soon disappears: it rises in invisible vapour, and floats buoyantly among the other constituents of the atmosphere.

These four substances the air everywhere and always contains, and the first two always in very nearly the same proportions. Thus Gay Lussac examined air collected at a distance of four miles from the earth's surface, and comparing it with air collected from the summit of the Alps, and from towns and villages, found no sensible difference. In 1852, Mr Welsh, under the direction of the British Association, examined air collected at an elevation of 18,000 feet above the earth, and, comparing it with air collected from the surface, both samples having been dried and freed from carbonic acid, found the one to contain 20.88 per cent of oxygen, the other 20.92. The exact and numerous experiments of many other analysts have shown the constancy of the composition of the air. The four substances we have just mentioned are all necessary to the daily wants of animal and vegetable life; but two of them, oxygen and nitrogen, form so large a proportion of the whole, that we are accustomed to say of dry air, that it consists of nitrogen and oxygen only, in the proportion of 4 gallons of the former to 1 of the latter. More correctly, however, air, when deprived of the watery vapour and carbonic acid it contains, consists, in 100 gallons, of 79 of nitrogen mixed with 21 of oxygen; or of—

	By measure.
Nitrogen, ...	79
Oxygen, ...	21
	100

It has been calculated that the atmosphere of our globe contains 2,551,586 *billions* of pounds of oxygen; and that the yearly consumption of this oxygen, in the respiration of men and animals, together with the processes of ordinary combust-

ion, amounts to two and a quarter billions of pounds. Thus, in a hundred years the consumption would only reach 225 billions—that is, not even the ten-thousandth part of the whole.

The carbonic acid exists in the air in very small proportion. At ordinary elevations there are only about 4 gallons of this gas in every 10,000 of air; $\frac{1}{2500}$th part of the whole. There are some grounds for concluding that the proportion of carbonic acid gas is somewhat greater at a considerable height. Even this increased quantity is very small; and yet the presence of this gas is essential to the existence of vegetable life on the surface of the earth.

But being heavier than common air, it appears singular that the proportion of this gas should increase as we ascend into the atmosphere. Its natural tendency would seem to be rather to sink towards the earth, and there to form a layer of deadly air, in which neither animal nor plant could live. But independent of winds and aerial currents, which tend to mix and blend together the different gases of which the air consists, all gases, by a law of nature, tend to diffuse themselves through each other, and to intermix more or less speedily, even where the utmost stillness prevails and no wind agitates them. This is the "law of gaseous diffusion," discovered by Graham, according to which heavy gases intermix with light gases, somewhat as wine is intermixed with water. If certain fluids of different densities be mingled, such as mercury and water, they separate again immediately they are left at rest; but two gases of different densities, when brought together, immediately begin to intermix, and the greater the difference in their densities, the more rapidly will they mingle. Although chlorine is nearly 36 times heavier than hydrogen, they rapidly intermix, and never separate when left at rest. Hence a light gas like hydrogen (see p. 19) does not rise wholly to the uppermost regions of the air, there to float on the heavier gases; nor does a heavy gas like carbonic acid sink down so as to rest permanently beneath the lighter gases. On the contrary, all slowly intermix, become interfused, and mutually intercorporated, so that the ammonia, the carbonic acid, and the other gases which are produced in nature, may be found everywhere through the whole mass, and a comparatively homogeneous mixture uniformly over-

spreads the whole earth. In obedience to this law, carbonic acid in all places slowly rises or slowly sinks, as the case may be, and thus, on the whole, a uniform purity is maintained in the air we breathe. Even in badly ventilated rooms it is pretty uniformly diffused, though it may amount to 10, up to 70 parts in 10,000 of air. In the case of crowded theatres, however, the air near the roof has been found to contain more carbonic acid than that at the level of the stage, the impure air ascending because expanded by heat. If it seems to linger in sheltered hollows like the deadly gas-lake of Java, it is because the fatal air issues from the earth more rapidly than it can diffuse itself upwards through the atmosphere; and if it rest more abundantly on the mountain-top, it is because the leaves of plants, and the waters of the sea, absorb it from the lower layers of the air faster than it can descend to supply their demands.

The watery vapour varies in quantity with the climate and temperature of the place. It is less in cold seasons and climates generally than in such as are hot. It seldom forms more than $\frac{1}{60}$th, or less than $\frac{1}{200}$th of the bulk of the air. In England it rarely happens that the air contains less than two-thirds of the whole quantity of watery vapour which it could take up, and very often it is quite saturated. But on the other hand, only $\frac{1}{15}$th of the maximum amount of moisture was found in a sample of air from the coast of the Red Sea, during a simoom.

The presence of carbonic acid in the atmosphere is shown by the formation of a white film of carbonate of lime on the surface of lime-water when this is exposed to the air. The presence of watery vapour may be shown on the hottest days by pouring ice-cold water into a tumbler or water-bottle, when the vapour of the air will rapidly condense on the outer surface of the vessel in the form of drops of dew.

The purposes which we know to be served by these several constituents of the atmosphere show both that they are all essential to the composition of the air, and that in quantity as well as kind they have been beneficently adjusted to the composition, the wants, and the functions of animals and of plants.

Thus, as to the oxygen—

From every breath of air which the animal draws into its

lungs it extracts a quantity of oxygen. The oxygen thus obtained is a part of the natural food of the animal, which it can obtain from no other natural source, and new supplies of which are necessary to it every moment. The oxygen of the atmosphere, therefore, is essential to the very existence of life in the higher orders of animals.

The candle burns, also, and all combustible bodies kindle in the air, only because it contains oxygen. This gas is a kind of necessary food to flaming and burning bodies; so that, were it absent from the earth's atmosphere, neither light nor heat could be produced from coal, wood, or other combustible substances.

But the proportion, also, in which oxygen is present in the air is adjusted to the existing condition of things. Did the atmosphere consist of oxygen only, the lives of animals would be of most brief duration, and bodies once set on fire would burn so fast as to be absolutely beyond control. The oxygen is therefore mixed with a large proportion of nitrogen. This gas, not being poisonous, as carbonic acid is, harmlessly dilutes the too active oxygen. It weakens and prolongs its action on the system as water dilutes wine or spirits, and assuages its too fiery influence upon the animal frame.

Then, as to the carbonic acid—

Every green leaf that waves on field or tree sucks in, during the sunshine, this gas from the air, but only in the day-time; during the night the action ceases. Two processes do indeed occur during the day, but then the exhalation of oxygen far exceeds its absorption. In the night the reverse process only takes place, though but to a very slight extent, a little carbonic acid being exhaled, and oxygen sucked in. But very young leaves, shoots, and flowers exhale nothing but carbonic acid, and consequently actually vitiate the atmosphere like animals, by throwing carbonic acid into it and drawing oxygen from it. Carbonic acid is as indispensable to the life of the plant as oxygen is to the life of the animal. Remove carbonic acid from the air, and all vegetable growth would cease. It must therefore be a necessary constituent of the atmosphere of our earth.

But carbonic acid is poisonous to animals; not, as is usually said, because it is in itself a poison, but because, when more than a certain proportion of it exists in the atmosphere, res-

piration becomes impossible. If carbonic acid be absorbed, or injected into the veins of an animal, no poisonous effect will follow—it will be eliminated in the lungs; but if, instead of being *in* the body, the carbonic acid is *outside* of the body, in the air, then respiration, or the exchange of carbonic acid for oxygen, will not take place, and *this* will be in effect poisonous. It is for this reason that the proportion of this gas contained in the air is so very small. Were this proportion much greater than it is, animals, as they are now constituted, could not breathe the atmosphere without injury to their health—not even were the amount of oxygen proportionately increased, for respiration is hindered by too much carbonic acid, no less than by too little oxygen.[1] On the other hand, that growing

[1] The most remarkable natural example of an atmosphere overloaded with carbonic acid gas is the famous Poison Valley in the island of Java, which is thus described by an eyewitness:—

"We took with us two dogs and some fowls to try experiments in this poisonous hollow. On arriving at the foot of the mountain we dismounted and scrambled up the side about a quarter of a mile, holding on by the branches of trees. When within a few yards of the valley we experienced a strong nauseous suffocating smell, but on coming close to its edge this disagreeable odour left us. The valley appeared to be about half a mile in circumference, oval, and the depth from thirty to thirty-five feet; the bottom quite flat; no vegetation; strewed with some very large (apparently) river stones; and the whole covered with the skeletons of human beings, tigers, pigs, deer, peacocks, and all sorts of birds. We could not perceive any vapour or any opening in the ground, which last appeared to us to be of a hard sandy substance. It was now proposed by one of the party to enter the valley; but at the spot where we were this was difficult at least for me, as one false step would have brought us to eternity, seeing no assistance could be given. We lighted our cigars, and, with the assistance of a bamboo, we went down within eighteen feet of the bottom. Here we did not experience any difficulty in breathing, but an offensive nauseous smell annoyed us. We now fastened a dog to the end of a bamboo eighteen feet long, and sent him in: we had our watches in our hands, and in fourteen seconds he fell on his back, did not move his limbs or look round, but continued to breathe eighteen minutes. We then sent in another, or rather he got loose, and walked in to where the other dog was lying. He then stood quite still, and in ten minutes fell on his face, and never afterwards moved his limbs: he continued to breathe seven minutes. We now tried a fowl, which died in a minute and a half. We threw in another, which died before touching the ground. During these experiments we experienced a heavy shower of rain; but we were so interested by the awful sight before us that we did not care for getting wet. On the opposite side, near a large stone, was the skeleton of a human being, who must have perished on his back, with his right hand under his head. From being exposed to the weather the bones were bleached as white as ivory. I was anxious to procure

plants may be able to obtain a sufficiently large and rapid supply of carbonic acid from a gaseous mixture which contains so little, they are made to hang out their many waving leaves into the atmosphere. Over the surface of these leaves are sprinkled countless pores or mouths, which are employed during the day in separating and drinking in carbonic acid gas. The millions of leaves which a single tree spreads out, and the constant renewal of the moving air in which they are suspended, enable the living plant to draw an abundant supply for all its wants from an atmosphere already adjusted to the constitution of living animals.[1]

This constant action of the leaves of plants is one of the natural agencies by which the proportion of carbonic acid in the lower regions of the atmosphere is rendered less than it is in the higher regions.

So, also, the watery vapour of the atmosphere is not less necessary to the maintenance of life. The living plant consists of water to the amount of nearly three-fourths of its whole weight, and from the surface of its leaves water is continually rising during the day into the air in the form of invisible vapour. Were the air absolutely dry, it would cause this water to evaporate from the leaves more rapidly than it could be supplied to them by the soil and roots. Thus they would speedily become flaccid, and the whole plant would droop, wither, and die.

The living animal in like manner is made up for the most part of water. A man of 154 lb. weight contains about 110 lb. of water, and only 44 lb. of dry matter. From his skin and from his lungs water is continually evaporating. The amount of water thus evaporated is 3½ lb. daily, of which one-third comes from the lungs, and two-thirds from the skin.

this skeleton, but any attempt to get it would have been madness."—LOUDON. The Grotta del Cane, near Naples, is a small cavern on the inner side of the rampart of a volcanic crater. Thence a constant stream of carbonic acid pours out, but a man's mouth is above the level of the deadly gas, though a dog entering the cavern soon becomes insensible.

[1] A common lilac-tree, with a million of leaves, has about four hundred thousand millions of pores or mouths at work, sucking in carbonic acid; and on a single oak-tree as many as seven millions of leaves have been counted. Lindenau calculated that the surface of the lungs of an adult man which is in contact with the air, reaches the enormous extent of two thousand six hundred and forty-two square feet!

Were the air around him perfectly dry, his skin would become parched and shrivelled, and thirst would oppress his feverish frame. The air which he breathes from his lungs is loaded with moisture. Were that which he draws in entirely free from watery vapour, he would soon breathe out the fluids which fill up his tissues, and would dry up into a withered and ghastly mummy. A frog kept in an artificially dried atmosphere soon perishes. It is because the simoom and other hot winds of the desert approach to this state of dryness, that they are so fatal to those who travel on the arid waste.

Thus the moisture which the atmosphere contains is also essential to the maintenance of the present condition of both animal and vegetable life: it pervades the leaves and all the tissues of plants, and finds admission to the lungs and general system of animals.

There are, besides, other beautiful purposes which this moisture serves. The air when charged with moisture does not permit the heat of the earth to radiate through it into space and so be lost, but offers a greater obstacle to its escape than does dry air. And when the summer sun has sunk beneath the horizon, and coolness revisits the scorched plant and soil, the grateful dew descends along with it and moistens alike the green leaf and the thirsty land—the invisible moisture of the air thickens into hazy mists, and settles in tiny pearls on every cool thing. How thankful for this nightly dew has nature everywhere and always appeared, and how have poets in every age sung of its beauty and beneficence!

Let us attend for a moment to the cause of this descent of the dew, and to the way in which it seems to select, as it were, the spots on which it will fall.

All bodies on the surface of the earth radiate, or throw out rays of heat in straight lines—every warmer body to every colder—and the whole earth itself is continually sending rays of heat upwards through the clear air into free cold space. Thus on the earth's surface all bodies strive, as it were, after an equality of temperature (an equilibrium of heat), while the surface as a whole tends gradually towards a cooler state. But while the sun shines on any spot this cooling will not take place, for the surface there receives for the time more

heat than it gives off; and, when the sun goes down, if the clear sky be shut out by a canopy of clouds, these will arrest and again throw back to the earth a portion of the heat which escapes by radiation, and will thus prevent it from being dissipated. At night, then, when the sun is absent, the earth will cool the most—on clear nights also more than when it is cloudy; and when clouds only partially obscure the sky, those parts will become coolest which look towards the clearest portions of the heavens.

Again, the quantity of vapour which the air is capable of holding in suspension is dependent upon its temperature. At high temperatures, in warm climates, or in warm weather, it can sustain more—at low temperatures, or in cold weather, less. Hence, when a current of comparatively warm air, loaded with moisture, ascends to, or comes in contact with, a cold mountain-top, it is cooled down, is rendered incapable of holding the whole of the vapour in suspension, and therefore leaves behind, in the form of a mist or cloud encapping the lofty summit, a portion of its watery burden. The aqueous particles which float in this mist appear again on the plains below, in the form of streams or springs, which bring nourishment at once, and a grateful relief to the thirsty soil.

So, when the surface cools by radiation, the air in contact with it must cool also; and, like the warm currents on the mountain-side, must forsake a portion of the watery vapour it has hitherto retained. This water, like the floating mist on the hills, descends in particles almost infinitely minute. These particles collect on every leaflet, and suspend themselves from every blade of grass in drops of "pearly dew."

And mark here a beautiful adaptation. Different substances are endowed with the property of radiating their heat, and of thus becoming cool, with different degrees of rapidity. Those substances which in the air become cool first must also attract first, and most abundantly, the particles of falling dew. Thus, in the cool of a summer's evening the grass-plot is wet, while the gravel-walk is dry; and the thirsty pasture and every green leaf are drinking in the descending moisture, while the naked land and the barren highway are still unconscious of its fall.

And from the same atmospheric store of watery vapour come the refreshing showers which descend in our temper-

ate zone, and the rushing rains which fall in torrents within the tropical regions—only the mode in which they are made to descend is somewhat different.

In the upper regions of the atmosphere currents of cold air are continually rushing from the north, and currents of warm air from the south. When two such currents of unequal temperature, each loaded with moisture, meet in the atmosphere, they mix, and the mixture has the mean temperature of the two; but air of this mean temperature is incapable of holding in suspension the mean quantity of watery vapour contained in the two currents. Hence, as on the mountain-side, a cloud is formed, and the excess of moisture, collecting into drops, falls to the earth in the form of rain.

When we consider how small a proportion of watery vapour exists in the air—that were it all to come down at once over the whole earth, it would cover the surface only to a depth of 5 inches—we cannot think without amazement of the vast and continuous effects it produces. The quantity of rain which falls yearly on our Islands would cover them, were it all to fall at once, to a depth of from 25 to 30 inches; and, except the table-land of central Spain, there are few places in western Europe where the depth of yearly rain is less than 20 inches. And all this rain descends from an atmosphere which does not contain more, probably, at any one time, than falls yearly in dew alone over the whole earth.[1]

In descending, also, this rain discharges another office: it washes the air as that passes through it, cleansing it from dust and organic particles, and dissolving and carrying down those accidental vapours which, though unessential or even unwholesome to man, are yet fitted to assist the growth of plants. It thus ministers in another double manner to our health and comfort, purifying the air we breathe, and feeding the plants on which we live.

As soon, again, as the rain ceases to fall, and the clear sky permits the sun's rays once more to warm the surface of the earth, vapours begin to rise anew, and the sweeping winds

[1] How, among the hills in tropical countries, the rain really rushes down may be inferred from the fact, that among the Khassaya hills, north of Calcutta, the yearly fall of rain amounts to 610 inches (50 feet), of which 550 fall in the six rainy months, beginning in May. As much as 25½ inches have been observed to fall in a single day.

dry up the rains and dews from its moistened surface. The rapidity of evaporation depends also upon the dryness of the air: this is so great during the hot winds of the East that drops of water vanish as if by magic. There are regions of the globe, also, where unending summer plays on the surface of the wide seas, and causes a perpetual evaporation to lift up unceasing supplies of water into the air. These supplies the wind wafts to other regions; and thus the water which descends in rain or dew in one spot, is replaced by that which mounts up in vapour from another.—And all this to maintain unbroken that nice adjustment which fits the constitution of the atmosphere to the wants of living things!

How beautiful is the arrangement by which water is thus constantly evaporated or distilled, as it were, into the atmosphere—more largely from some, more sparingly from other spots—then diffused equally through the wide and restless air, and afterwards precipitated again in refreshing showers which cleanse the tainted air, or in long-mysterious dews! But how much more beautiful the contrivance—I might almost say the instinctive tendency—by which the dew selects the objects on which it delights to fall; descending first on every living plant, copiously ministering to the wants of each, and expending only its superfluity on the unproductive waste!

And equally kind and bountiful, when understood, Nature is seen to be in all her operations. Neither skill nor materials are ever wasted; and yet she ungrudgingly dispenses her favours apparently without measure, and has subjected dead matter to laws which compel it to minister, and yet with a most ready willingness, to the wants and comforts of every living thing.

Four substances, therefore—oxygen, nitrogen, carbonic acid, and watery vapour—are essential to the composition of the atmosphere, and they are adjusted, both in kind and quantity, to the existing condition of things. But besides these, the air contains also many other substances in minute and indefinite proportions. Of these, some are formed in the air itself, some rise in vapour from the surface of the earth, and some ascend from the waters of the sea.

Of those which are formed in the air itself, two are deserving of especial mention—ozone, and nitric acid.

The former of these is merely oxygen gas in what is called a more exalted chemical condition than that in which it usually exists. To comprehend what is meant by a more exalted chemical condition, we must understand that even simple elements exist under very different forms; thus sulphur exists as a yellow, crystalline, and brittle substance, soluble in carbon disulphide and other liquids; but it also exists as a non-crystalline or amorphous and insoluble substance. Carbon is crystalline and opaque in *plumbago*, crystalline and transparent in *diamond*, formless and black in *soot*. Similarly, oxygen may be passive, as in the *air;* and active, as in the form of *ozone*. These differences of state are known to chemists as Allotropism. Ozone is an allotropic condition of oxygen. It received this name from the powerful odour which characterises it. Into this condition it is brought by the action of a discharge of electricity, and possibly by other agencies. In this form it acts upon, and combines more readily with, all other substances. Among the other useful purposes it is supposed to serve, I mention the oxidation—that is, the combination with oxygen—of the organic, often noxious, substances which rise into the atmosphere, and of those vegetable and other compounds in the soil, upon which depend its general fertility, and the abundant production of the food of plants. Ozone possesses considerable power of bleaching; and when iron or copper is moistened, it absorbs the ozone from the atmosphere, and becomes oxidised, or *rusted*, at its surface. A proof of the exalted chemical condition in which oxygen exists when under the form of ozone, is seen in the fact that it oxidises silver; whereas oxygen, under the ordinary form in which it exists in the air, has no influence on silver.

Ozone (or else a substance known as peroxide of hydrogen and having many of the properties of ozone) is probably never absent from the atmosphere; but it is always present in a proportion too minute to admit of being determined either by weight or by measure. It is more abundant in winter, on the tops of mountains, and after a storm has purified the air. It is probably more serviceable to us than we are yet aware of.

Nitric acid, the other important substance I have mentioned as being formed in the air, is probably more abundant than

ozone. It is commonly known by the name of aquafortis, and consists of nitrogen, oxygen, and hydrogen. Every flash of lightning which darts across the sky, every electric spark, great or small, which in any other form passes through the air, causes a minute proportion of nitrogen and oxygen along the line of its course, to unite together, and, with water, to produce nitric acid. And as this passage of electricity through the air is frequent almost everywhere, and in the tropical regions is distinctly visible nearly every day of the year, I am inclined to regard this acid as a constant constituent of atmospheric air. Whether it is essential or indispensable to the present condition of things, we have not as yet the means of determining; but it has been ascertained by actual experiment that this acid is at least very frequently present in the air, even of European countries; and falling rain is sometimes actually sour from the quantity of nitric acid it contains. This acid is very favourable to vegetable growth—and is, indeed, one of the substances which the falling rains and dews are appointed to wash out of the air, and in doing so to bring down to plants a valuable form of food, which is thus daily prepared for them among the winds of heaven. On an average about 2 lb. of nitric acid annually fall upon each acre in Europe.

From the surface of the earth, again, there arise continually into the air vapours and gases of various kinds. The vegetable and animal bodies which undergo decay in manifold circumstances, and the numerous substances which are burned in the air, all produce chemical compounds, which, being volatile or gaseous, ascend and mingle with the atmosphere. Some of these, like ammonia and sulphuretted hydrogen, are perceptible to the smell, while others are altogether inappreciable by the senses. The steaming marsh also, beneath the summer's sun, sends forth fatal miasms which prostrate the body in fever, though neither the senses can perceive, nor our more refined chemical tests as yet detect, their presence; living volcanoes likewise belch forth their vapours; and a thousand chemical operations, natural and artificial, pour out their fetid steams and volatile exhalations. All these ascend from the earth, are caught by the winds, wafted more or less speedily from their birthplace, and mingle with the general air. Thus the atmosphere must contain accidental substances

almost without end, which are not essential to its constitution, and which rise into the aerial sea because of their lightness, just as liquid impurities spontaneously flow, or solid impurities are washed down by the rivers into the waters of the great ocean.

Of these substances which thus ascend from the earth in the form of gas, ammonia deserves especial notice, because of the important function which some agricultural writers have ascribed to it in reference to vegetable growth. This gas, which is familiar to every one in the smell of common hartshorn, is formed during the putrefaction of animal and vegetable substances in the presence of water and air, and is the principal cause of the smell which heaps of such putrefying matters give off. It is continually rising, therefore, into the atmosphere from many parts of the earth's surface. It has consequently been found in very minute quantity in the air where it has been sought for. Some therefore deem it an essential constituent of our air. In this respect, however, it must be distinguished from nitric acid, which we know to be produced in the atmosphere itself by purely physical causes, and to be altogether independent, so far as its occurrence in the atmosphere is concerned, of the previous existence of life. It is possible that ammonia may be so produced also; indeed it would seem that when pure hydrogen, and substances containing hydrogen, are burnt in the air, traces of nitrite of ammonia are formed. Perhaps we shall have to acknowledge ammonia as an essential constituent of the atmosphere, and to discover in its existence, and constant reproduction there, a wise provision for the maintenance of vegetable growth.

Further, from the ever-moving sea, the winds which raise it into rolling waves, and lash it into foam, sweep upwards the light spray, and mingle it with the rushing air. Thus, far inland and over high mountains, the salty particles are carried, and thus a part of all the constituents of sea-water is mingled with the universal atmosphere. Hence the host of foreign substances which must float around us, commingled with those which we know to be absolutely necessary to the maintenance of animal and vegetable life, is almost inconceivable. Every gallon of rain-water that falls in England contains on the average half a grain of the salts of the sea. Once, during a storm, not less than 6½ grains of common salt were

found in each gallon of rain-water that fell at Cirencester, Gloucestershire. This salt had come in sea-spray driven by the wind 35 miles from the Bristol Channel.

The accumulation of all these foreign matters in the air would, in course of time, render it unwholesome to animal life—perhaps unfit for the healthy development even of vegetable forms. But the waters of heaven, as I have described, ascend and descend continually to wash and purify it: they serve as a natural conservative check. They *scrub* the atmosphere.

Thus, simple as the air appears, its scientific history as a whole is somewhat complicated. The adjustment of its constituents involves many interesting particulars, and the arrangements by which the constant presence of its essential constituents is secured, both in kind and quantity, are very numerous; yet we cannot fail to perceive both a physical beauty and a wise contrivance in them all.

CHAPTER II.

THE WATER WE DRINK.

Importance of water in nature.—Composition of water.—Hydrogen gas; how prepared; the lightest of known substances, and an inflammable gas; exists in nearly all combustible substances; is always converted into water when these substances are burned.—In water hydrogen is combined with oxygen.—What is meant by a chemical combination.—Water without taste and smell; importance of this.—Cooling property of water.—Relation of water to other liquids.—It dissolves many solid substances; hence natural waters never pure.—Quantities of mineral matter in some river, lake, spring, and sea waters.—Composition of the solid matter in sea-water; in the Thames water at Kew; and in that of the Kent Water Company.—Lime held in solution in water by carbonic acid.—Why calcareous waters encrust their channels, petrify, and deposit sediments in boilers.—Impurity of spring waters in large towns, about farmhouses, and near graveyards.—Well-waters in the *dunes* of Bordeaux; their analogy to the waters of Marah.—Water absorbs its own bulk of carbonic acid at all pressures.—How this explains the liveliness of champagne and soda-water, the bursting of bottles, the briskness and deadness of beer, &c.—Excess of oxygen in the air contained in water; importance of this to the lives of fishes.—More oxygen near the surface of the sea.—Why air obtained from snow contains less oxygen than the atmosphere.

THE water we drink is next in importance to the air we breathe. It forms three-fourths of the weight of living animals and plants, is the most abundant compound substance we meet with on the face of the earth, and covers, to an unknown depth, at least three-fourths of its entire surface.

Pure water consists of two simple or elementary subtances,[1] oxygen and hydrogen. The former of these exists

[1] By *simple* or *elementary* substances, chemists understand such as cannot by any known means be resolved or split up into more than one constituent:

also in common air, and has been described in the previous chapter.

Hydrogen is a kind of air or gas which, when pure, is without colour, taste, or smell. It differs, however, from all the three gases (oxygen, nitrogen, and carbonic acid) described in the preceding chapter; *first*, in being far lighter than any of them—indeed the lightest of all known substances; and, *second*, in taking fire, and burning in the air when a lighted taper is brought near it.

It is readily prepared by putting a few pieces of metallic zinc or iron into a bottle or flask, and pouring over them a quantity of oil of vitriol (sulphuric acid) diluted with twice its weight of water. When a sufficient quantity of the gas has been produced to drive out all the common air from the bottle, a gas jet-burner, or a bit of glass tube, or of a tobacco pipe thrust through a cork, may be put into the mouth of the bottle, when a jet of gas will issue which may be lighted by a taper. It burns with a very pale flame. When a perfectly dry, cool, glass tumbler or bottle is held over the flame dew will be seen to condense on the inner side of the glass, and will gradually collect into little visible globules, and finally trickle down in the form of drops of pure water. This water is formed by the burning of the hydrogen from the bottle in the oxygen of the air. During this burning it *combines* with the oxygen, and water is produced. The extreme lightness of the hydrogen may be shown by extinguishing the gas, and causing it to ascend into a small empty balloon of gold-beater's skin or of collodion, tied to the jet. When the balloon is full of gas it will readily ascend, showing not only that the hydrogen is lighter than common air, but that it is so much lighter as to be able to raise heavy bodies through the air along with it. It is to the lightness of this gas that we owe the power of travelling through the air in ordinary balloons.

Hydrogen exists in a great many other substances besides water—in bituminous coal, in wood, in oils and fats, in coal-gas, and in nearly all combustible substances; but whenever it is completely burned in the air, water is formed by its

sulphur, phosphorus, gold, silver, iron, &c., are examples of such simple substances. 65 elements are known, but not more than 14 form an essential part of all plants and animals.

union with oxygen, as in the burning of the simple jet above described. Thus, in nearly all cases of combustion, water is one of the substances produced, though it generally rises into the air in the form of invisible vapour.

Water thus formed consists of oxygen and hydrogen, in the proportions by weight of—

			Per cent.
Oxygen, ...	16	or	88.89
Hydrogen, ...	2	,,	11.11
	18	,,	100.00

—or every 9 lb. of pure water contain 8 lb. of oxygen and 1 lb. of hydrogen; and it is called in chemical language protoxide of hydrogen. The water with which we are familiar in common life, always and everywhere out of the laboratory, contains some admixture of earthy and alkaline salts, organic particles, and dissolved gases.

In atmospheric air, as we have seen, there are at least four substances present which are essential to its existence. But between air and water there is this important chemical distinction, that in the former the constituents are merely mixed together, while in the latter they are *chemically combined.* When nitrogen and oxygen are *mixed* together to form common air, each of them retains its gaseous form, and all its properties unaltered; but when hydrogen and oxygen are *combined* to form water, they severally lose both their original gaseous form, and all their distinctive properties, physical and chemical. Water is not light, like hydrogen, nor will it burn as that gas does; neither will ordinary combustible bodies burn in it as they do so readily and brilliantly in oxygen gas.

Now, when bodies combine chemically, they always form a new substance different in its properties from those which have been employed in producing it; and, indeed, it is one of the wonders which modern chemistry has made known to us, that hydrogen, which burns so readily, should form so large a part of water, our great extinguisher of flame; and that oxygen, so indispensable to animal life, should form eight-ninths of a liquid in which few terrestrial animals can live for more than three or four seconds of time.

That water is indispensable to animal and vegetable life,

appears both from its forming so large a proportion of the bodies of living animals and plants, and from some other considerations which have been stated in the preceding chapter. But many of the properties which water possesses are wonderfully conducive to our comfort, to the supply of our daily wants, and to the maintenance of the existing condition of things.

1°. Thus, even the unheeded property of its freedom from smell and taste is important to animal comfort. Sweet odours are grateful to our nostrils at times, and pleasant savours give a relish to our rarer kinds of food. But health fails in an atmosphere which is ever loaded with incense and perfumes, or where the palate is daily pampered with high-seasoned dishes and constant sweets. The nerves of smell and taste do not bear patiently a constant excitement, and the whole body suffers when a single nerve is continually jarred. Hence it is that water and air, which have to enter so often into the animal body, and to penetrate to its most delicate and most sensitive organs and tissues, are made so destitute of active and sensible properties that they can come and go to any part of the frame without being perceived. Noiselessly, as it were, they glide over the most touchy nerves; and, so long as they are tolerably pure, they make a thousand visits to the extremest parts of the body without producing the most momentary irritation or sense of pain. Externally, also, they can be applied to the most delicate, inflamed, or skinless parts of the body, not only without irritating, but generally with the most grateful and soothing effects. These negative properties, which are common both to air and water—though, as I have said, they are rarely thought of—are nevertheless most essential to our daily comfort.

2°. Again, water possesses a cooling property, which is very grateful to all living things. The priceless value of water in "a dry and thirsty land" arises mainly from the necessity of constantly supplying that which, in a dry and warm atmosphere, is constantly evaporating from the skin and the lungs. But in all climates water has a cooling power, which gives it a new value to the hot and fevered animal. When taken into the mouth and stomach, or when poured over the inflamed skin, it cools more than an equal weight of any other liquid or solid substance we could apply. This

arises from the circumstance, that it takes more heat to give a sensible warmth to water than to an equal weight of any other common substance. Thus the same quantity of heat which is required to raise the temperature of 1 lb. of water a single degree (from 60° to 61° for example), would give an equal increase of temperature to 30 lb. of quicksilver; and so, again, to convert water into vapour, requires more heat than an equal weight of any other common liquid such as ether or spirit of wine. Hence, when water evaporates from the skin, it serves as a constant cooler of the surface; while the vapour which escapes with the breath, cools equally the interior of the body. It is really very interesting to observe how the great capacity of liquid water for heat makes it so gratefully cooling as it enters the body; and how its still greater capacity for heat, when passing from the liquid state to the state of vapour or steam, enables it so constantly to bear away from us the heat of fever, as it escapes from our bodies in the form of insensible vapour.

3°. But the peculiar composition of water enables it to provide all plants, and indeed all animals, with a most important part of their very substance. It not only carries food into the plant, but also constitutes a veritable part of the products which the plant forms and of which it is built up. The same is true of animals.

4°. Further, pure water possesses the property of mixing with some other fluids, such as alcohol (strong spirits) in all proportions, merely weakening or diluting their strength. With others, again—as with oil—it refuses to mingle. Solid substances it has the property of dissolving; and upon this property depend many of the most useful purposes served by water, in reference both to animal and vegetable life.

If a piece of sugar and a piece of glass be put together into a quantity of water, the former will dissolve and disappear, while the latter will remain for any length of time in the water practically unaltered in form or in weight. Water does not dissolve all bodies therefore. Sugar is soluble, glass insoluble, in this liquid.

Again, if into two equal quantities of water we introduce loaf-sugar and common salt—the sugar into the one and the salt into the other—as long as they are respectively dissolved and disappear, we shall see that 1 lb. of cold water will dis-

solve perhaps 3 lb. of sugar, forming a thick syrup, while it will dissolve 4 oz. only of common salt. Thus, of those substances which dissolve in water, some are much more soluble —disappear, that is, in larger quantity—than others.

In nature, as we have said before, water is never found chemically pure: that which descends in rain is contaminated by the impurities it washes out of the air; that which rises in springs, by the substances it meets with in the earth itself. In rivers the impurity of the water is frequently visible to the eye. It is often of a red colour as it flows through rocks of red marl which contain much oxide of iron in their composition; it descends milky from the glaciers of Iceland and the slopes of the Andes, because of the white earth it holds in suspension; it is often grey or brown in our muddiest English rivers; it is always brown where it issues from boggy lakes, or runs across a peaty country; it is sometimes black to the eye when the quantity of vegetable matter is excessive, as in the Rio Negro of South America; and it is green in the Geysers of Iceland, in the Swiss lakes, among the islands of the South Sea, and around our own Islands, because of the yellow matters which it everywhere holds in suspension or in solution. Only in clear and deep waters—like those of the Bay of Naples, and in parts of the Pacific, where minute objects may be seen on the bottom some hundreds of feet down — is the real blue colour natural to water, in large masses, distinctly perceptible. This is the blue which is seen in the azure grotto of the Isle of Capri, and in the deep indigo-like waters of some parts of the Mediterranean and Adriatic seas.

But among the rocky and other materials which water meets with in and upon the earth, there are many which it can dissolve, as it does salt and sugar, and the presence of which cannot be detected by the sense of sight. Hence the clearest and brightest of waters—those of springs and transparent rivers, even when filtered—are never chemically pure; they all contain in solution a greater or less quantity of saline matter, sometimes so much as to give them a decided taste, and to form what are hence called *mineral* waters.

Among the purest natural waters hitherto examined is that of the river Loka, in the north of Sweden, which flows over hard impenetrable granite and other rocks, upon which water

produces little impression. It contains only $\frac{1}{20}$th of a grain (0.0566) of solid mineral matter in the imperial gallon. Some waters in the granite regions of the north of Scotland, and even some springs which rise through the greensand in Surrey, contain as little as 4 or 5 grains in the gallon. The water which is supplied to the city of Edinburgh contains 7 to 14 grains in the gallon,[1] that of Loch Katrine as delivered in Glasgow about 3, and that of the Thames, near London, about 21. These are comparatively pure waters, and are very good for general consumption. That of the river Wear, which supplies the city of Durham, contains 15½ grains in the gallon, and is still a good water for domestic use. That which is used in the town of Sunderland, and is obtained from the lower new red sandstone, contains 27 grains in the gallon. Some of the other waters supplied to and used in London and its neighbourhood, and which are not derived from the Thames, contain—

Water Companies.	
New River,	19½ grs. in the gallon.
East London,	23½ " "
Kent,	29¾ " "

Other drinking-waters contain more than these. Some which are in constant use contain twice as much—even the waters of the holy Jordan contain 73 grains to the gallon—but generally, in the waters of average purity which are employed for domestic purposes, there are not present more than from 20 to 30 grains of solid matter in the imperial gallon. This is not a large amount when stated in the convenient form of a *percentage*, for 20 grains of solid matter in an imperial gallon of water corresponds to the presence of no more than .029 of a per cent. Some important lake and river waters are here given:—

	Grains per gallon.
Boston (U.S.) Water-works,	1.22
Charles River, Massachusetts,	1.67
Bala Lake,	1.95
Loch Katrine,	1.96
Thirlmere,	3.60
Schuylkill River, Philadelphia,	4.26
Detroit River, Michigan,	5.72

[1] This is 10 to 20 parts by weight in 100,000 of the waters—a gallon of pure water at 60° Fahr. weighing 70,000 grains.

	Grains per gallon.
Ohio, at Cincinnati,	6.74
Spree, at Berlin,	7.98
Loire, at Orleans,	9.38
Danube, near Vienna,	9.87
Lake of Geneva,	10.64

The nature of the drinking-water supplied to 107 of our seaside resorts in England and Wales has been carefully examined by Wigner.[1] The softest water is that of Plymouth, which shows less than 3 grains of total solid matter per gallon and but ½ a degree of hardness.[2] The most saline water amongst the public supplies was that of Walton-on-the-Naze, which showed the following results on analysis :—

	Grains per gallon.
Total solids,	228.8
Common salt,	182.9

Its hardness was nearly 21 degrees. But a private well-supply in a hotel at Filey showed no less than 64 degrees, and was otherwise so impure with really dangerous and offensive animal matters as to be no better than filtered sewage. The chief results of the inquiry may be briefly summarised thus :—

Number of places.	Quality of Water.	Residents.	Visitors.
53	First-class (good)	450,000	1,300,000
34	Second-class (doubtful)	260,000	360,000
5	Third-class (bad)	60,000	40,000

In 16 of the above cases the public water-supply is supplemented by private or public wells, many of suspicious or dangerous character. But there are 15 watering-places which have no public supply, and in 11 of these the well-waters are decidedly bad.

Generally speaking, rain-water which falls in remote country districts is the purest; then comes river-water; next, the water of lakes; after these, common spring waters; and then the water of mineral springs. The waters of the Black Sea, and the Sea of Azof, which are only brackish, follow next; then those of the great ocean; then those of the Mediterranean, an inland sea; and last of all come those of lakes which, like the Dead Sea, and Lake Aral, possess no known outlet, and contain as much as 24 per cent of salt.

[1] Seaside Water. G. W. Wigner. 1878.

[2] For an explanation of this term see further on, p. 28.

The following table shows the percentage of total salts or solid dissolved matters in various sea-waters :—

Black Sea, Crimea,	.18	Mediterranean (Venice),	2.91
Caspian Sea, near Pishnoi,	.63	Do. (Marseilles),	4.07
Sea of Azof,	1.19	German Ocean (Havre),	3.27
Baltic,	1.77	Dead Sea,	24.05

All the solid matter which the rivers carry into the sea remains there, while the water which brings it is continually rising again in vapour. This vapour, as we have seen, descends in the form of rain on the interior of continents, and there dissolves, and thence carries down new supplies of mineral matter to the sea. In this way saline matter has accumulated in the ocean till its waters have become briny and bitter to the taste. In the same way, also, it has accumulated in the Aral Lake and Dead Sea—the more rapid evaporation and the unfrequent rains having aided in making these inland waters so much salter than those of the great oceans. The waters of the great ocean, and its branches, contain from 2200 to 2800 grains of saline matter in the gallon; those of the Dead Sea in some places 11,000; in others, as much as 21,000 grains, or one-fourth part of their whole weight. Those of a small lake east of the steppes of the Wolga, contain as much as three-fifths of their weight of saline matter. It will perhaps convey an idea of the prodigious amount of salts contained in the ocean, if we mention that, assuming the correctness of Humboldt's measurement of the depth to be an average of 900 feet, Professor Schafhaütl, of Munich, has calculated the entire quantity of salts at $4\frac{1}{4}$ millions of cubic miles, of which our ordinary table-salt forms no less than 3,051,342 cubic miles. If the whole Alpine range of mountains were crumbled to powder, and dissolved in water, it would only form a fifth of this enormous quantity of salts. And if, instead of Humboldt's average of 900 feet, we calculate on the basis of Laplace's measurement, which is 3000 feet, the whole range of the Himalaya mountains would not form much more than a third of the solid matters thus dissolved in sea-water.

Common salt is the most abundant kind of saline matter which occurs in sea-water; but it contains also the chlorides of calcium and magnesium,[1] and some other salts, in con-

[1] *Chlorine* is a greenish-yellow gas, which combines with metals and forms

siderable proportion. One examination of sea-water has been made by Riegel. His sample, taken off the coast of Havre, contained, in 1000 parts by weight, $31\frac{1}{2}$ parts of solid matter (2250 grains in the gallon), consisting of—

Chloride of sodium (common salt), ...	24.632
Chloride of potassium, ...	0.307
Chloride of calcium, ...	0.439
Chloride of magnesium, ...	2.564
Bromide of magnesium, ...	0.147
Sulphate of lime (gypsum), ...	1.097
Sulphate of magnesia[1] (Epsom salts), ...	2.146
Carbonate of lime (chalk), ...	0.176
Carbonate of magnesia, ...	0.078
	31.586

The reader will observe that, next to common salt, the compounds of magnesia are most abundant in sea-water. The same is the case with the waters of the Dead Sea and other very salt lakes, and to this they chiefly owe their acrid bitter taste.

Besides the substances above named, traces of phosphate of lime, of silica, of the oxides of iron and manganese, of fluorine, and even of lead, copper, silver, gold, and arsenic, have been detected in sea-water. Although only traces of iodine can be detected, yet we know that sea-weeds contain large quantities of it, and they must abstract it from the water. Indeed, we know that, being the common reservoir into which all soluble substances are washed down by the rains and rivers, we ought to find in the sea traces of all the soluble substances which are capable of existing together in the same solution. Sea-water also contains dissolved gases, carbonic acid, for example, being present to the extent of from 4 to 7 parts by weight in 100,000. Sea-water is, of course, heavier than river-water; its specific gravity varies from 1024 to 1028.

Even the spring and river waters employed for domestic purposes often contain a considerable variety of substances. Thus the water of the Thames, taken at Kew by the Grand Junction Water Company, and that supplied to London by

chlorides; bromine, a dark-red liquid, forms *bromides; iodine*, a lead-grey solid, forms *iodides*.

[1] Sulphuric acid, or oil of vitriol, uniting with lime, magnesia, soda, &c., forms *sulphates* and water.

the Kent Water Company, contain respectively, in an imperial gallon—

	Thames water.	Kent Water Company
Carbonate of lime (chalk),	10.90 grs.	7.02 grs.
Sulphate of lime (gypsum),	3.26 "	11.03 "
Nitrate of lime,	trace	0.07 "
Carbonate of magnesia,	1.17 "	3.42 "
Chloride of sodium (common salt),	1.40 "	3.50 "
Sulphate of soda,	0.18 "	—
Chloride of potassium,	—	0.44 "
Sulphate of potash,	0.61 "	0.70 "
Silica,	0.45 "	0.76 "
Iron, alumina, and phosphates,	0.67 "	trace
Organic matter, with a trace of ammonia,	3.07 "	2.61 "
	21.71 "	29.55 "

Lime, in combination with carbonic acid (carbonate), and with sulphuric acid (sulphate), is the most abundant substance in these two waters. Indeed it very often exists in large quantity, especially in spring-waters; and it is chiefly to the lime and magnesia they contain, that what are called *hard* waters owe their property of curdling with soap. Pure waters are always soft; and when a water is tolerably soft, it may be inferred that it does not contain any large proportion of lime or magnesia.

Waters which contain much lime are often bright and sparkling to the eye, and agreeably sweet to the taste. They generally become somewhat milky when boiled, and leave a sediment, which incrusts the inside of kettles or boilers. When strongly impregnated with lime, they will even deposit a calcareous coating along their channels as they flow in the open air, or will incrust, or petrify, as it is called, any solid substances which are immersed in them. These circumstances are owing to the peculiar way in which the lime is held in solution.

We have already seen that, if a current of carbonic acid (a gas which contains one combining proportion of carbon weighing 12, united with two combining proportions of oxygen each weighing 16) be made to pass through lime-water, the transparent liquid will become at first milky, from the formation of carbonate of lime, which remains suspended in the form of a very fine powder; but if the current of carbonic acid be continued, the milkiness will gradually disappear, the

carbonate of lime will be redissolved, and the liquid will again become clear. The carbonate of lime is held in solution by an excess of carbonic acid.

If, now, the clear solution be poured from one vessel to another for a number of times, it will gradually give off this excess of carbonic acid into the air, and become milky again. This is what happens when calcareous springs incrust the sides of their channels, as in Auvergne, or at Matlock and Knaresborough in our own country. Or if a coin or other solid substance be introduced into the solution, bubbles of carbonic acid gas will gradually be given off, and the coin or substance will become incrusted with lime—the carbonate of lime which falls. This is exactly what takes place in a petrifying well. Or if the solution be heated over the fire, the excess of carbonic acid is driven off, the solution becomes milky as before, and the whole of the lime falls in the form of carbonate, leaving the water nearly pure. The incrustation in our kettles and boilers is chiefly produced in this latter way. Hard waters, therefore, are generally made much softer and purer by boiling. Should much of the lime, however—as in the water supplied by the Kent Water Company, above noticed—be in the state of gypsum, mere boiling will not alone soften it so far as that ingredient is concerned; but if a little soda be added to it during the boiling, this will separate the lime of the gypsum also.

But there is a much better and cheaper process for softening hard water than that of boiling it named above. This is Clark's process, an ingenious plan now carried out on a large scale by the water companies of Canterbury, Tring, the Colne Valley, and Caterham. At Canterbury, 110,000 gallons are softened daily by the addition of 11,000 gallons of lime-water. Thus lime is added to remove lime. But this puzzle is easily solved. The lime added takes away that excess of carbonic acid which held the carbonate of lime present in the water in solution, both that and the newly formed carbonate falling together. Thus the water is softened and purified.

As the solvent power of water enables it to take up many substances from the rocks and soils through which it passes, it often happens that, in the neighbourhood of dwellings and farmyards, and especially in towns, the water of wells becomes very impure, and even unwholesome to drink. The rains that

fall upon the filth accumulated in towns wash out the soluble substances it contains, carry them into the soil, and through this, by degrees, to the wells by which the wants of the inhabitants are supplied. This has often been productive of serious and fatal disease. It shows, therefore, the propriety of preventing, as far as possible, the accumulation of refuse, and, where such accumulation is unavoidable, of placing it at the greatest distance from wells which yield water for daily use. And, especially, it shows the necessity of bringing water from a distance for the supply of large cities.

The neighbourhood of graveyards is equally fitted, with the accumulation of town refuse, to adulterate water with undesirable admixtures. The water of a well close to the old churchyard on the top of Highgate Hill was examined by the late Mr Noad, and found to contain as much as 100 grains of solid matter to the gallon, 57 grains of which consisted of the nitrates of lime and magnesia. This large amount of *nitrates*[1] is traced to the neighbouring graveyard, as such compounds are generally produced where animal matters decay in porous soils. A curious fermentation occurs, due probably to a minute organism, which works in the dark, turning ammonia, and indirectly other compounds of nitrogen, into nitrates. While the buried bodies were more recent, animal matters of a more disagreeable kind would probably have been found in the well, as I have myself found them in the water of wells situated in the neighbourhood of farmyards.

Well-waters sometimes contain vegetable substances also of a peculiar kind, which render them unwholesome, even over large tracts of country. In sandy districts the decaying vegetable matters of the surface-soil are observed to sink down and form an ochrey *pan*, or thin yellow layer in the subsoil, which is impervious to water, and through which, therefore, the rains cannot pass. Being arrested by this pan, the rain-water, while it rests upon it, dissolves a certain portion of the vegetable matter; and when collected into wells, is often dark-coloured, marshy in taste and smell, and unwholesome to drink. When boiled, the organic matter coagulates, and when the water cools separates in flocks, leaving the water whole-

[1] The *nitrates* are formed from nitric acid (aquafortis) combined with lime, magnesia, &c. Saltpetre is *nitrate of potash*, formed from nitric acid combined with potash,—and so on.

some, and nearly free from taste or smell. The same purification takes place when the water is filtered through charcoal, or when *chips of oak wood are put into it.* These properties of being coagulated by boiling, and by the tannin of oak wood, show that the organic matter contained in the water is of an albuminous character, or resembles white of egg. As it coagulates, it not only falls itself, but it carries other impurities along with it, and thus purifies the water—in the same way as the white of egg clarifies wines and other liquors to which it is added.

Such is the character of the waters in common use in the *Landes* of the Gironde around Bordeaux,[1] and in many other sandy districts. The waters of rivers, and of marshy and swampy places, often contain a similar coagulable substance. Hence the waters of the Seine at Paris are clarified by introducing a morsel of alum, and the river and marshy waters of India by the use of the nuts of the *Strychnos potatorum*, of which travellers often carry a supply. One of these nuts, rubbed to powder on the side of the earthen vessel into which the water is to be poured, soon causes the impurities to subside. In Egypt, the muddy water of the Nile is clarified by rubbing bitter almonds on the sides of the water-vessel in the same way.

In these instances the clarification results from the iron compounds or the albuminous matter being coagulated by what is added to the water, and in coagulating it embraces the other impurities of the water, and carries them down along with it. Salt, and many saline matters, have likewise the power of clearing many kinds of thick and muddy water. So long as the water contains but little dissolved matter, all its particles of mud remain a long time suspended. But the addition of almost any soluble salt, even in small proportion, will, as it were, curdle the impurities, causing them to collect together and to settle.

These cases, and especially that of the sandy Landes of Bordeaux, and elsewhere, throw an interesting light upon the history of the waters of Marah, as given in the fifteenth chapter of Exodus.

"So Moses brought Israel from the Red Sea, and they went out into the wilderness of Shur; and they went three

[1] Fauré—Annales de Chem. et de Phys., Septembre 1853, p. 84.

days in the wilderness, and found no water. And when they came to Marah, they could not drink of the waters of Marah, for they were bitter: therefore the name of it was called Marah. And the people murmured against Moses, saying, What shall we drink? And he cried unto the Lord, and the Lord showed him a *tree*, which when he had cast into the waters, the waters were made sweet."[1]

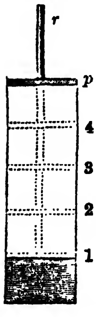
As in our European sandy dunes, the waters of the sandy wilderness may contain an albumen-like substance which an astringent plant will coagulate. The discovery of such a plant among the natural vegetation of the desert would give, therefore, the means of purifying and rendering it wholesome, as cuttings of the oak-tree render salubrious the waters of the Landes of La Gironde.

5°. Water, also, absorbs or dissolves different kinds of air or gas in different proportions; and upon this property depend some things which are familiar to us in common life, and which, therefore, it may be proper to mention. Thus—

First, It absorbs at the ordinary temperature about its own bulk of carbonic acid gas—and it does so under every pressure.

The meaning of this is explained as follows. We take a strong, tall, glass jar (fig. 1), graduated into five equal divisions, and provided with an air-tight piston, *p*. Into this jar we pour pure water up to the first division (1), fill up the jar quickly with carbonic acid, fit in the piston and shake the jar. The piston will then gradually sink one division (to 4)—that is, the water will dissolve or absorb its own volume of the gas, under the ordinary pressure of the atmosphere. But if, the arrangement being as before, we begin the experiment with fresh water and gas, and apply at once to the piston-rod *r* a pressure equal to another atmosphere—15 lb. to the square inch—the piston will immediately sink two divisions (to 3), or the gas will be compressed to half its bulk. If the whole be now shaken, the piston will, as at first, gradually sink one division (to 2). In other words, the water will again absorb its own bulk of the gas under this increased pressure.

Fig. 1.



[1] Exodus, xv. 22-25.

Or, if we apply at once a pressure of three atmospheres—45 lb., making, with the ordinary atmosphere, four in all, or 60 lb. to the inch, which press upon it—the piston will sink at once three divisions (to 2), reducing the gas to one-fourth of its bulk. If, now, the water be agitated, the piston will again gradually sink one division, and the whole gas will disappear—that is, the water will again absorb its own bulk of the gas at this new pressure.

If, now, the applied pressure of 45 lb. be removed, the gas will gradually rise out of the water and force up the piston, till it finally rests, as in the first experiment, at the division No. 4, the water retaining only its own bulk of the gas at the ordinary pressure of one atmosphere, and at the common temperature. But the lower the temperature the more gas will be kept in solution. Thus 1 pint of water just at the freezing-point will dissolve as much as 1¾ pint of carbonic acid gas.

It is because of this interesting property that, with the aid of machinery, water can be overcharged with carbonic acid in the soda-water manufactories, and that the gas escapes with so much violence from a soda-water bottle when the cork is withdrawn.

But the result is the same whether the carbonic acid ready prepared be forced into the water—as is done by the soda-water maker—or be formed in the bottle itself from substances contained in the water. The latter is the case in all fermenting liquors contained in bottles. The carbonic acid is gradually produced in the interior of the bottle during the progress of the chemical change we call fermentation. As fast as it is produced the water dissolves it, the pressure of the gas upon the inner surface of the bottle increasing at the same time. If the bottle be of sufficient strength, the only consequence is, that the cork will be forced out if not firmly tied down; or that, when the cork is withdrawn, the gas will drive out the liquor in its own eagerness to escape. If the bottle be too weak, it will be burst by the pressure, as often happens with soda-water; and, sometimes, to thousands of bottles at a time in champagne cellars, this occurring when the internal force of the gas exceeds about seven times that of the pressure of the atmosphere. In other wines, and in beer and porter, especially when well hopped, carbonic acid is produced in

smaller quantity. But it is to the presence of this gas, dissolved in this way, that the latter liquors owe their briskness when poured from the bottle, and to the natural escape of the gas that they become flat, stale, or dead, as we say, when they are exposed to the air.

Water absorbs also the gases, oxygen and nitrogen—of which the atmosphere chiefly consists—but not in the precise proportions in which they exist in the air. We have seen that the air we breathe contains about 21 per cent of oxygen, but in the dissolved air which we can extract from fresh clean lake or river water it exists to the amount of 31 to 33 per cent. This, among other purposes, is an adaptation to the wants of fishes, and generally of those marine animals which extract the oxygen they require for the support of life, from the water in which they live. They can obtain the necessary supply of this gas more easily from air which contains one-third than from air which contains only one-fifth of this vital principle. If proof of this were required, it is found in the observation that, where circumstances have been such as to deprive river-water of a portion of its oxygen, the fish have been found dead in great numbers.

This tendency of water to dissolve more oxygen, in proportion to the nitrogen, than exists in common air, explains another curious circumstance which long puzzled philosophers as well as ordinary people. If a bottle be filled quite full with snow, be well corked, and then put into a warm room, the snow will melt, and the bottle will be filled, perhaps one-third with water and two-thirds with air. If this air be examined, it will be found to contain less oxygen than atmospheric air—sometimes not more than 12 or 14 per cent; while atmospheric air, as we have seen, contains 21 per cent. Hence it was long supposed that the air, always present in snow, naturally contained this small portion of oxygen, and that snow, therefore, possessed some peculiar property of absorbing the gases of the atmosphere in this new proportion. But the explanation is, that the snow, in melting into water, takes up a larger proportionate quantity of the oxygen than it does of the nitrogen of the air which was contained in its pores, and consequently leaves a smaller proportion behind. Snow-water, also, contains a small but variable quantity of ammonia, which is also found in rain-water and in dew.

Thus the water we drink, like the air we breathe, is a substance of much chemical interest. Both are indispensable to the existence of life; both are mixed in nature with many substances not essential to their composition; and both, in their most important properties, exhibit many direct relations to the growth of plants and to the wants and comforts of living animals.

CHAPTER III.

THE SOIL WE CULTIVATE.

General origin of soils; natural differences in their quality; how they arise.—Stratified and unstratified rocks.—Soils of the stratified rocks.—Improved soils where different rocks intermix.—Soils of the granites, traps, and lavas.—Agency of rains, winds, and vegetable accumulations in producing diversities of soil.—General chemical composition of soils.—Illustrations afforded by the Atlantic border of the United States.—Some plants affect sandy soils, others clay soils, and yet do not always flourish upon them.—Cause of this.—Minute chemical composition of the soil; its mineral and organic parts.—Chemical difference between granite and trap soils.—Dependence of fertility on chemical composition.—Influence of rain and moisture, and of the degree of warmth, on comparative fertility.—District floras and crops.—Influence of man in modifying geological, chemical, and climatic tendencies.—Progress of exhausting culture in new regions; example of North America.—Reclaiming influences of human exertion; example of Great Britain.

In immediate importance to man, the soil he cultivates is scarcely inferior to the air he breathes, or the water he drinks. Upon the plants which the soil produces he and all other animals depend for their daily sustenance. Hence, where the soil is fruitful, animal life is abundant; where it yields only sparingly, animals are few, and human inhabitants, as a general rule, but sparsely scattered.

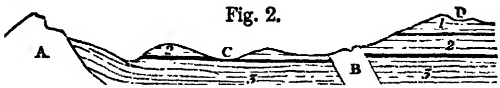
The soil is formed, for the most part, from the rocks of which the crust of the earth is composed. By the action of air and water, aided by alternations of heat and cold, these rocks crumble, and their surface becomes covered with loose materials. The seeds of plants are sprinkled over them by the winds; they germinate and grow up; animals come to

feed upon them; both plants and animals die; and thus a mixture of decayed rock, with the remains of animals and plants, gradually overspreads the entire surface of the dry land. It is to this mixture that we apply the name of soil.

But the soil thus naturally formed differs in quality, from various causes. The rocks which crumble differ in chemical composition; their crumbled fragments are spread over the surface, and sorted by wind and water in different ways; and the kind and quantity of the animal and vegetable matters they are mixed with differ much. Through the agency of these and similar causes of diversity, many varieties of soil are produced, which are not only unlike to each other in their sensible properties, but very different also in their agricultural value.

If we examine with a little attention the numerous rocks we meet with in travelling over a country like our own, an important difference in their physical structure will soon strike us. Some are seen to form hills, cliffs, or mountains, which consist each of a single huge lump or mass, cracked here and there, perhaps irregularly, but exhibiting no continuous division into distinct parts or portions. Others again are as clearly divided into layers or beds, spread over each other like vast flagstones of different thicknesses, sometimes extending horizontally for distances of many miles. The following section (fig. 2) exhibits these differences of physical appearance.

Fig. 2.

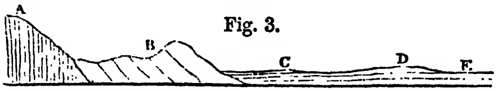


The rocks marked A and B are the undivided masses, those marked C D are the rocks which lie in beds. The numbers 1 2 3 indicate the groups into which the beds, when numerous on any spot, can usually be subdivided.

Those most ignorant of science can observe differences of this kind—it requires only the use of the eyes; and yet this difference of structure is so important, that upon it is founded the division of all rocks into *stratified* and *unstratified*. Those which are composed of beds or strata are called stratified; those in which no such partings are visible are called unstratified.

The stratified rocks cover by far the largest portion of the earth's surface. They are not always quite horizontal, as represented in the above section; indeed they are more often inclined, so as to dip into the earth at a greater or less angle. Sometimes they are even piled against each other like flagstones placed on edge. The following section (fig. 3) ex-

Fig. 3.



hibits these three several modes in which the stratified rocks occur, A showing them on edge, B dipping at a considerable angle, and C D E perfectly horizontal. This disposition of the rocks, it will be seen, must materially affect the quality of the soil, and especially the extent of surface over which any particular soil is to be found. If the quality of the soil depend in any degree upon the quality of the rock, the changes of soil must be very frequent where the surface is formed of the edges only of different rocks, as is seen at A and B.

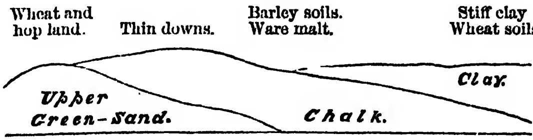
These stratified rocks consist essentially of one or more of three different kinds of matter only: limestones, sandstones, and clays, more or less hard, form the substance of them all. When a limestone crumbles, it forms a calcareous soil; a sandstone, a sandy soil; and a hard clay rock, a more or less tenacious clay soil. Hence these are the three leading qualities of soil known and spoken of among practical men.

But many rocks do not consist altogether either of limestone, of sandstone, or of clay, but of a mixture of two of them, or of all three, in varied proportions. The crumbling of such rocks, therefore, gives rise to soils of various intermediate qualities, neither calcareous, properly speaking, nor sandy, nor clayey; and these form, for the most part, those more open, fertile, and valuable loams, which the farmers of every country prefer to cultivate.

Similar mixed soils are also naturally produced where the edges of different rocks overlap each other, and mingle their mutual *débris*. Thus, when the fragments of a rock rich in lime naturally intermix with one poor in this ingredient, the soil produced is of a much better and more useful quality than when the surface is formed by the fragments of one of the

rocks only. This is illustrated in the south of England in many places, where the materials of the clay, the chalk, and the greensand, meet and intermingle, as seen in the following section (fig. 4).

Fig. 4.



This woodcut represents the clay as coming in contact with the chalk which lies below it, and the chalk again coming in contact with the upper greensand, upon which it rests. At the first point of contact the heavy difficult clays change into open barley soils, producing a grain which, for quality and malting properties, is not excelled by any in the kingdom. And, again, at the contact of the chalk and upper greensand, the mixed soil is equally celebrated for its crops of wheat, and for the fertility of its hop-gardens.

The unstratified rocks, again, may be represented by three varieties—the granites, the traps, and the lavas. These rocks also crumble more or less rapidly, and produce soils which, in granitic countries, are generally poor, over trap-rocks generally rich, and upon decayed lavas often remarkable for fertility. In the granite districts of Devonshire and Scotland we see the poor soils which this rock produces; and in the low country of Scotland, and in the north of Ireland, the rich soils of the trap. Italy and Sicily, and every other volcanic country in the Old World, exhibit in their soils the fertilising influence of the modern lavas.

In the new countries the same phenomena reappear, similar rocks everywhere producing similar soils. Thus, at the base of the famous gold-bearing mountains of Victoria, stretches "a fertile and beautiful country—the garden of Australia Felix—the rich soil of which is the product of decomposed lava."[1] And for ages, probably, after the gold-mines have been forgotten, these rich park-like plains will continue to yield luxuriant harvests of golden grain to the industrious cultivator.

[1] Quarterly Journal of the Geological Society, ix. 75.

But the earth's surface is varied with hill and valley, mountain and plain, so that the rains which fall are able to flow along the slopes, and to gather themselves into rivulets, streams, and rivers. In so flowing they wash out the finer and lighter particles from among the fragments of the crumbled rocks, and carry them into the valleys and plains. The constant repetition of this washing gradually sorts the fragments of each rock, spreading the finer portions on the lower ground and along the courses of rivers, and leaving on the hills and slopes the coarser and less easily transported materials.

Hence from the same rock different varieties of soil arise. Coarse sands and gravels may overspread the higher ground, while fine sand, clays, or loams, are carried farther and cover the plains or valleys beneath. From a mixed stratified rock the clay or lime may be washed out and spread over the low plains, leaving only a poor and barren sand on the slopes above; or from a decaying granite the felspar-clay may be washed down, leaving the hungry and unfertile quartz to cover the naked rock.

In some countries, winds play a similar part. They lick up the fine dust as they sweep over a country, and carry it often far away to other regions; or, rushing from the sea, they bear inland the sands of the shore, and cover with sandy dunes or barren desert soils which are naturally rich and productive in vegetable food.

Thus physical causes modify the quality of the soils which rocks differing in chemical composition naturally tend to produce. They assort or rearrange the materials of which a rock consists, and they often bear to great distances, and spread over other rocks, the finer particles into which it crumbles. The so-called alluvial soils, which border so many of our rivers, are produced by such a sorting, brought about through the agency of water. The sea-shore also often illustrates the breaking down of rocks and the sorting of their materials according to their specific gravity, their size and their shape. The sandy downs of European countries, and many of the desert regions of Africa and Asia, owe their existence to the sorting agency of the wind.

Vegetation also has its influence. When a tree or humbler plant dies on a dry surface, it gradually decays, and dis-

appears almost entirely into the air. Let it be immersed in stagnant water, and thus excluded from the air; it blackens, falls to pieces, and crumbles, perhaps, but in substance long remains where it fell. Let others grow up, die, and fall on the same moist spot, and the black vegetable matter will accumulate from year to year. In this way, where shallow water rests on an impervious bottom, peat-bogs and other collections of vegetable matter gradually cover the surface. They bury the fragments of the crumbled rock sometimes under a great depth of vegetable matter, and form those unmanageable peaty soils which overspread so large a portion of Scotland, and especially of the north and west of Ireland.

Such are the principal natural causes of diversity in soils. In the chemical composition and physical or mechanical structure of the rocks we recognise the fundamental or primary cause; in the varied distribution of the physical and chemical actions of heat and cold, of moving and of freezing water, and of rains and winds, important secondary causes; and in the growth and accumulation of vegetable matter, another more special and less widely operating agent in the production of such diversities. The action of animal life, also, must not be forgotten.

By these agencies are formed the varieties of soil generally described as sandy soils, clay soils, limestone or marly soils, and peaty soils. These terms all indicate important chemical differences, though practical men have hitherto had their attention too little drawn to the influence which chemical composition exercises over agricultural value. The sandy soil is distinguished by consisting chiefly of quartzose or silicious sand—another form of flint, rock-crystal, or the substance which chemists call *silica;* the limestone or marly soil, by containing much limestone, chalk, or other variety of what chemists distinguish as *carbonate of lime;* the clay soils, by abounding in clay, a compound substance, consisting chiefly, besides silica, of that to which chemists give the name of *alumina,* together with some chemically-combined water.

But the economical value of a soil is often naturally affected by physico-geological considerations, which are altogether independent of the chemical composition of the rock from which it is formed. The mere physical character of the rock, for example, from which the soil is formed, often determines

not only the kind of husbandry which can be profitably followed, but the class of farmers by whom the land is to be occupied, and even whether it can be profitably cultivated at all. The chalk-rocks present an illustration of this. These are in most countries very porous and absorbent. Wells sunk into them yield no water, and superficial pits, to receive and retain the rain-water, are the main resource of the inhabitants. This, with the thin soils and short grass of our chalk-downs, has long determined the conversion of the chalk-wolds into extensive sheep-walks. But in countries by climate and otherwise unsuited to sheep, and where the little rain that falls is soon licked up by the heats of summer, this use of the land becomes impossible, and an artificial supply of water becomes indispensable to the existence of permanent and extended cultivation. To obtain this, deep wells sunk through the chalk are the only available resource, and this at once determines that the possessors must be men of large means, or at least that the land must be worked by a class of wealthy cultivators. The upper portion of the State of Alabama, in North America, is in this condition. Situated on the porous chalk, it is destitute of surface water, unless where the rivers pass. In a hot climate, its herbage is burned up in summer, so that it is unsuited for a pastoral husbandry. It grows some flinty wheat, but it is almost equally unsuited to be an extensive producer of grain. Devoted chiefly to the cotton culture, it is held in large properties, and hundreds of deep Artesian wells already riddle the country, and yield the needful supplies of water.

The following section (fig. 5) of the Atlantic coast-line of North America, from the sea to the mountains, will serve to illustrate nearly all the points I have brought under the notice of the reader in the preceding part of this chapter, in reference at least to the stratified rocks. This section shows—

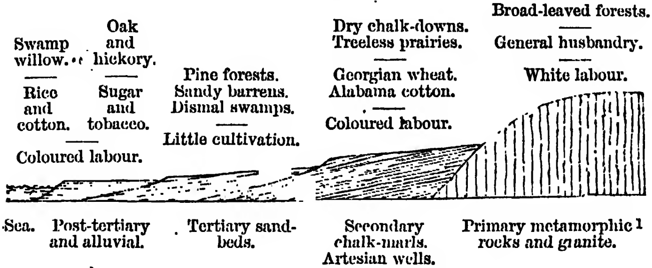
1°. How, over large tracts of country, the rocks are seen to be at different angles of inclination; some, as in the high land to the right, standing on their edges; and some, as the layers of alluvial soil on the sea-shore, lying nearly on a level.

2°. How, over extended areas, the surface rock may consist chiefly of clay, as in the post-tertiary and alluvial deposits near the sea; of sand, as in the tertiary beds; of limestone, as in the chalk-marls; and of mixed materials, as on the hills,

where numerous thin beds resting on their edges rapidly succeed each other.

3°. How the character of the soil changes distinctly with

Fig. 5.



the surface rock—being rich and productive on the post-tertaries, sandy and barren on the tertiaries, dry and chalky on the secondary marls, useful and loamy on the slopes of the older mixed and metamorphic rocks.

4°. How the natural vegetation and the artificial produce of the soil vary in like manner; and how the kind of husbandry, and we might almost say the social state, is determined by the character of the dead rocks. It is certain, at least, that the *profitable employment* of slave[2] instead of free labour depends very much upon the character of the superficial rocks, of the soils they yield, and of the crops they can readily be made to grow.

5°. And lastly, how dismal peaty swamps disguise the natural character of the surface in some regions; and how the want of water in others renders profitable cultivation impossible, unless, by expensive borings, it can be brought up from great depths.

The amount of chemical knowledge embodied in the general chemical description of soils already given, is useful and satisfactory as explaining their general origin, and is sufficient even to direct the practical man in reference to certain economical operations. Long experience and observation, for example, have made generally known to practical men that

[1] The word metamorphic here used means changed or altered—as clay, for example, is changed when it is baked into tiles or bricks.

[2] These observations, though no longer wholly applicable to the Southern United States, are retained in the text in consequence of their general interest.—ED.

certain cultivated plants and trees prefer or grow best upon sandy soils, others on limestone soils, others on clay soils, and others again on soils of a mixed or loamy character. If one of these trees or plants is to be grown, therefore, a sandy or other soil suited to it is sought for; or if a sandy or clay soil is to be profitably planted or cultivated, the tree is selected which has been seen to flourish, or the crop which has yielded profitable harvests, on other sands or clays of a similar kind.

But when we come to inquire more particularly into the relations between plants and soils, this elementary chemical knowlege fails us. The same plants do not flourish on all sands, on all clays, or on all marls equally. Why is this? Or the trees flourish for a while, and then die out; or the crop for a few years yields remunerative returns, and then ceases to give a profitable harvest. How are these changes to be explained? The soil is as sandy, the clay as stiff, and the marl as rich in lime as ever, and yet the plants which formerly rejoiced in the several soils now refuse to grow in them!

A more minute chemical examination often answers these questions, and suggests a remedy for the evil complained of. This examination shows—

First, That when a weighed portion of perfectly dried soil, of any kind on which plants are capable of growing, is heated to redness in the air, a part of it burns away, and what is left is found to have sensibly diminished in weight. The combustible portion which thus disappears consists of the animal and vegetable (or organic) matter, of which all soils contain a sensible quantity, and of combined water. In some the proportion of organic matter is very small, as in the sandy soil on which the oil-palm flourishes in many African localities, and where the cinnamon-tree grows at Colombo, in Ceylon, which latter contains only one per cent of organic matter. In others it is very large, as in our own peaty soils, many of which lose upwards of three-fourths of their weight when burned in the air.

Secondly, That the earthy incombustible part of the soil—besides the silica of the sandy soils, the alumina of the clays, and the lime of the marly soils—contains various other substances, occasionally in large proportions. Among these,

potash, soda, magnesia, oxide of iron, and sulphuric acid, are the most abundant, while potash and phosphoric acid[1] are the most important. A few other substances, as chlorine and manganese, are also present.

In all soils upon which plants grow well and in a healthy manner, every one of these substances exists. If they or one of them be altogether absent, the plant refuses to grow. If they or one of them be present in too small quantity, the plant will be stunted and unhealthy. If the same kind of plant be grown for too long a time in the same soil, one or more of these substances will become scarce, or will not exist in an available form suitable for absorption by the plant, and hence the roots will be unable to obtain as much of them as the health and growth of the plant require. It is plain enough, therefore, why plants often refuse to grow even on the kind of soils they especially prefer, and why, having grown well on them for a while, they refuse to do so any longer. The soil does not contain all they require for their support, and in the proper form; or having once contained them all in sufficient proportions, it does so no longer. And the remedy for this special evil is equally clear. Add to the soil the mineral ingredients which are deficient, or introduce them in an available form, and the plant will spring up with its old luxuriance. But accumulations of organic matter, or the presence of plant-poisons, may also be the cause of such defects, which burning or liming often cures.

In like manner, that part of the soil which burns away—the organic and volatile part—when minutely examined, is found to consist of numerous different forms of matter. These are all included, however, in one or other of two groups—those which contain the element nitrogen, described in the first chapter,[2] and those which contain none of this element. The nitrogenous compounds are never very abundant, but there are several of them in the volatile part of the soil. One of them is ammonia, another is nitric acid, or rather the nitrates of potash and lime; and a third, of less immediate use as plant-food, consists of a more complex substance or

[1] Sulphuric acid, so called from its containing sulphur, is the name given by chemists to oil of vitriol; and phosphoric acid is formed by adding water to the white substance produced when phosphorus is burned in the air.

[2] See "The Air we Breathe."

substances, to which the name of albuminoid matter is given. The latter material, by its slow decay, yields the two former.

As to those organic or combustible matters in the soil which are free from nitrogen, but contain carbon, hydrogen, and oxygen, they do not seem to nourish the plant directly, but only after they have been changed or oxidised into carbonic acid gas. This gas dissolves many of the mineral matters of the soil, and so enables the roots to take them in. Moreover, this organic matter helps to absorb and retain moisture, and many useful manurial matters, as ammonia and potash. Without a little organic matter, sandy soils, containing all other kinds of plant-food, may be barren through lack of moisture. Thus, in the absence of organic matter, the sand-loving plant may refuse to grow even in a sandy soil, or one which loves lime where lime abounds, even when all the other mineral matters it requires are abundant in the soil, because the necessary organic constituent is still wanting. The full remedy, therefore, is obtained only when we supply to the unproductive soil the necessary organic as well as the necessary inorganic or mineral matters of which it may stand in need.

I may in some measure illustrate this by referring to a special case, common in nature, and to which I have already alluded in the present chapter. The granitic rocks, I have said, produce generally poor, the trap rocks, on the other hand, generally fertile soils. To what difference in the mineral matter of the rocks is this economical difference in the soils chiefly to be ascribed?

If a piece of each of the two kinds of rock be submitted to analysis, a remarkable but almost constant difference is discovered in their comparative composition. Besides the silica and alumina of which I have already spoken as existing in clays, the granites contain a copious supply of potash and soda, with minute quantities of magnesia, lime, oxide of iron, and phosphoric acid. The traps, on the other hand, abound in all these ingredients; and as experience has shown that the presence of all, in sensible proportion, is necessary to make a soil fertile, one reason of the natural difference between granite and trap soils becomes apparent. The one is defective, while the other abounds in the mineral constituents of a fertile soil. And the means for improving the granite soils become

equally apparent. Add, as a first step, the mineral substances in which granite is deficient, and fertility may gradually ensue. It is for this reason that in granite countries the application of lime, in some of its forms, is a favourite practice —one discovered to be remunerative long before chemistry had shown the reason why. But the traps are not only more varied and rich in their constituent minerals, but their texture is such as to suffer more complete and rapid disintegration.

Although, therefore, the first use of the soil in reference to the general vegetation of the globe is to afford to plants a firm anchorage, so to speak, for their roots—and although the growth of many useful plants seems at first sight to be dependent on the rude and general question only, as to whether the soil they occupy be a sand, a clay, or a calcareous marl,—yet a minute chemical examination shows that their usefulness to plants is in reality dependent upon the presence of a large number of chemical substances, chiefly of mineral, but in a measure of organic origin. If these are present, any plants will grow upon them that are suited to their mechanical texture, and to the climate of the place. If they, or one of them, be absent, whatever be the texture of the soil, and whatever the climate, the plant will languish and die. And the whole art of manuring consists in adding to the soil those things in which it is deficient—at the right time, in a proper chemical and mechanical condition, and in the requisite proportions. What services, chemical and physiological, the several constituents of the fertile soil really render to the plant that grows upon it, will appear in the succeeding chapter.

But suppose all the necessary chemical adjustments to be made—the composition of the soil, that is, to be such as is usually attendant upon fertility—physical conditions and agencies often intervene to falsify the predictions of chemistry. Thus, the fall of rain may be too small to keep the land in that condition of moisture which is required for the growth of plants. Hence the wide and naked deserts which extend over the rainless regions of the earth's surface. Whatever be the chemical composition of the soil in these regions, vegetation is impossible, and the labour of man, except he bring in water, almost in vain. Or the surface of a country may be so flat that the rains which descend upon it can find no outlet. They stagnate, therefore, and render it unpropitious to

the cultivator, so that fertility cannot show itself, whatever the soil may contain, unless an easy escape for the superfluous water be first provided. Or the rains may fall unseasonably, as they do in Iceland, where they appear in the autumn, when the barley should be ripening, in far too copious showers to permit even this hardiest of grain crops to be cultivated with profit in the island.

So the thermal conditions of a region may interfere with its fertility. Chemistry says, "Let the soil contain the necessary constituents, and any crop will grow upon it." But physiology modifies this broad statement, by showing, *first*, that whatever be the chemical composition of the soil, it must possess a certain physical texture before this or that plant will grow well upon it. That which naturally affects a clay soil will not grow well upon a sand; so one which delights in a blowing sand will languish in a moorish peat, however rich in chemical ingredients it may be. And, *secondly*, that the *climate* of a place determines equally whether its naturally rich soils shall grow this crop or that. Upon the combined influences, in fact, of warmth, and of the amount and distribution of rain, which make up what we call climate, depend in a great degree the varied floras and cultivated crops of the different regions of the globe. Thousands of plants, which beneath the tropics produce abundantly, will in the same soil scarcely expand a flower when placed beneath an arctic sky.

However important, therefore, the geological origin of a soil and its chemical composition may be, where climate is favourable, neither is able to effect anything in the way of raising food for man, where a duly attempered moisture and warmth are wanting. Similarly, but in a less degree, the differences between one season and another affect this result.

But man also exercises an influence on the soil, which is worthy of attentive study. He lands in a new country, and fertility everywhere surrounds him. The herbage waves thick and high, and the massive trees raise their proud stems loftily towards the sky. He clears a farm from the wilderness, and ample returns of corn pay him yearly for his simple labours. He ploughs, he sows, he reaps, and from her seemingly exhaustless bosom the earth gives back abundant harvests. But at length a change appears, creeping slowly over and gradually dimming the smiling landscape. The corn is first less

beautiful, then less abundant, and at last it appears to die altogether beneath the resistless scourge of an unknown insect, or a parasitic fungus. In New England and the British provinces of North America the wheat is overwhelmed by the *fly*; in New Jersey and Maryland, the wide peach-orchards by the *borer*, and a mysterious disease called the *yellows*; and in Alabama the cotton plant by the *rust*. The farmer forsakes, therefore, his long-cultivated farm, and hews out another from the native forest. But the same early plenty is followed by the same vexatious disasters. His neighbours partake of the same experience. They advance like a devouring tide against the verdant woods. They trample them beneath their advancing culture. The axe levels its yearly prey, and generation after generation proceeds in the same direction—a wall of green forests on the horizon before them, a half desert and naked region behind.

Such is the history of colonial culture in our own epoch; such is the vegetable history of the march of European cultivation over the entire continent of America. From the shores of the Atlantic, the unrifled soil retreated first to the Alleghanics and the shores of the great lakes. These are now overpassed, and the reckless plunderer, axe in hand, scarcely retarded by the rich banks of the Mississippi and its tributary waters, is hewing his way forward to the Rocky Mountains and the eastern slopes of the Andes. No matter what the geological origin of the soil may be, or what its chemical composition; no matter how warmth and moisture may favour it, or what the staple crop it has patiently yielded from year to year, the same inevitable fate overtakes it. The influence of long-continued human action overcomes the tendencies of all natural causes.

I need scarcely refer, as special examples of this fact, to the tracts of abandoned land which are still to be seen along the Atlantic borders of Virginia and the Carolinas. It is more interesting to us to look at those parts of America which lie farther towards the north, and which, in modes of culture and kinds of produce, more nearly resemble our own.

The flat lands which skirt the lower St Lawrence, and which near Montreal stretch into wide plains, were celebrated as the granary of America in the times of the French dominion. Fertile in wheat, they yielded for many years a large sur-

plus for exportation; now they grow less of this grain than is required for the consumption of their own population. The oat and the potato have taken the place of wheat as the staples of Lower Canadian culture, and as the daily sustenance of those who live on the produce of their own farms.

So, in New England, the cultivation of wheat has gradually become unprofitable. The tiller of the worn-out soils of this part of the United States cannot compete with the cultivator of the fresh land yearly won by the axe and the plough from the western wilderness, and he is fain to betake himself to the raising of other crops. The peculiarly wheat-producing zone is yearly shifting itself more completely towards the west. This has long been evident to the careful observer, and to the collector of statistical data. I brought it distinctly before the public in my work on North America.[1] And a striking proof of the correctness of my views is afforded by the subsequent return of the United States census of 1850. From these it appears that, while the produce of wheat in the New England States in 1840 amounted to 2,014,000 bushels, it was reduced in 1850 to 1,078,000 bushels. So rapidly does the influence of human agency on the natural tendencies of the soil in these countries manifest itself. Great as the cereal produce of the States is, yet the American farmer gets but half the grain from an acre of land that the British farmer obtains.

But the influence of man upon the productions of the soil is exhibited also in other and more satisfactory results. The improver takes the place of the exhauster, and follows his footsteps on these same altered lands. Over the sandy forsaken tracts of Virginia and the Carolinas he spreads large applications of shelly marl, and herbage soon covers them again, and profitable crops. Or he strews on them thinner sowings of gypsum, and as if by magic the yield of previous years is doubled or quadrupled.[2] Or he gathers the droppings of his cattle and the fermented produce of his barnyard, and lays it upon his fields—when, lo! the wheat comes up luxuriantly again, and the midge, and the rust, and the yellows, all disappear from his wheat, his cotton, and his peach-trees! Arti-

[1] Notes on North America, vol. i. chap. xiii.

[2] For examples of both these results, see the Essay on Calcareous Manures, by Edward Ruffin, the publication of which in Virginia, in 1832, marks an epoch in the agricultural history of the slave States of North America.

ficial and concentrated manures, such as superphosphate of lime, nitre, potash salts and guano, for the direct restoration of the soil, with new and richer foods for the live-stock of the farm, and many other improvements in agriculture, based upon scientific knowledge, have all worked marvels in the same direction.

But the renovator marches much more slowly than the exhauster. His materials are collected at the expense of both time and money, and barrenness ensues from the easy labours of the one far more rapidly than green herbage can be made to cover it again by the most skilful, zealous, and assiduous labours of the other. But nevertheless, among energetic nations, this second tide follows inevitably upon the first, as they advance in age, in wealth, and in civilisation. Though long mismanagement has, in a minor sense, desolated large portions of north-eastern America, a new fringe of verdant fields has already begun to follow towards the west, though at a long interval, the fast-retiring green belt of the virgin forests. A race of new cultivators, taught to treat the soil more skilfully, to give their due weight to its geological origin, to its chemical history, to the conditions of climate by which it is affected, and to the reckless usage to which it has so long been subjected—this new race may—*will*, I hope, in time—bring back the whole region to more than its original productiveness. Both the inherited energy of the whole people, and the efforts which State agricultural societies, and numerous zealous and patriotic individuals in each State, are now making, justify us in believing that such a race of instructed men will gradually spread itself over the rural districts in every part of the Union. The previous success of the mother country guarantees a similarly successful result to their kindred exertions.

For we have not to go far back in the agricultural history of Great Britain to find a state of things not much differing from the present condition of the land in North America. We require to turn aside but a short way from the highroad, in some districts of England, still to find in living operation nearly all the defects and vices of the present American system of farming.[1] A century and a half has, I may say,

[1] See, for instance, the state of farming in Lancashire, as described in the Royal Agricultural Journal, vol. x. part 1.

changed the whole surface of our island. But what labour has been expended, what wealth buried in the soil, what thought lavished in devising means for its recovery from long-inflicted sterility! Chemistry has discovered, and commerce has brought in from all parts of the world new manurial riches, to replace those which a hundred previous generations had permitted rains and rivers to wash out of the soil, or to carry away to the sea. Mechanical skill has given us the means of tilling the surface economically, of bringing up virgin soils from beneath, and of laying dry that which over-abundant water had prevented our forefathers from utterly impoverishing; and scientific investigation has taught us how best to apply all these new means to the attainment of the desired end.

It may be said, with truth, that Great Britain at this moment presents a striking illustration of the influence of man in increasing the productiveness of the soil. This example guarantees, as I have said, the success of similar operations in the United States of America and in our British colonies; while the now advanced condition, especially of our chemical knowledge, both in regard to the soil which is to be cultivated, to artificial manures, to the economical use of cattle food, and to the plants we wish to grow, insures a far more easy and certain advance in the process of restoration in these countries than in past times could take place among ourselves; less waste of time and money in ill-adjudged experiments, and less cost of labour in all the necessary operations of husbandry.

CHAPTER IV.

THE PLANT WE REAR.

A perfect plant, what?—Effects of heat upon it.—Contains carbon, water, and mineral matter.—Relations of the plant to the air.—Structure of the leaf.—Its pores absorb carbonic acid, and give off oxygen gas.—Relations to water.—Structure of the root.—Purposes served by water.—Relations to the soil.—Plants affect peaty, sandy, loamy, or clayey soils.—Effects of the drain, of lime, or of manure.—The art of manuring.—How the colours of flowers may be changed.—Effect of culture upon wild plants.—The carrot, the cabbage, the turnip.—Garden fruits, flowers, and vegetables.—Supposed origin of wheat, and its varieties.—How these changes are produced.—Plants which follow the footsteps of man; why they follow him.—Rapidity of growth in favourable circumstances.—The yeast plant in grape-juice.—Manufacture of dry yeast.—Chemical changes within the plant.—Production of numerous peculiar substances—medicines, perfumes, and things useful in the arts.—The green of the leaf, and the poison of the nettle.—The covering of the ripe potato, apple, and young twig.—General purposes served by vegetation.—It adorns the landscape; in relation to dead nature, it purifies the atmosphere, produces vegetable mould, and forms deposits of combustible matter; in relation to living animals, it supplies subsidiary luxuries and comforts, but its main use is to feed them.—Numerous interesting chemical inquiries suggested by the natural diversities and different effects of the vegetable food consumed by herbivorous and omnivorous races.

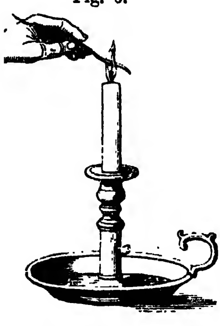
A familiarity with the chemical relations of the plant we rear makes still more apparent the relations of chemistry to the soil we cultivate.

A perfect plant consists essentially of two parts—the *axis* and its *appendages*. The upper or aerial part of the axis forms the *stem*, the lower or terrestrial part the *root*. The appendages of the axis are leaves and flowers, the latter consisting, in point of fact, of modified leaves.

When any part of a plant is heated in a close vessel, it gives off water, vinegar, and tarry matters, and leaves behind a black, bulky, coaly mass, known by the name of wood-charcoal; or if billets of wood be heaped up in the open air, covered carefully over with sods, and *smother*-burned, as it is called, with little access of air, the tar and other matters escape into the atmosphere, while the charcoal remains undissipated beneath the sod. This charcoal is an impure form of carbon. The manufacturer of wood-vinegar collects the volatile substances as the more important products. The charcoal-burner allows them to escape, the black residue being the object of his process. Both experiments, however, are the same in substance, and both prove that carbon and water form large parts of the weight of all plants.

If a piece of wood-charcoal be burned in the air it gradually disappears; but when all combustion has ceased, there remains behind a small proportion of ash. The same is seen if a portion taken from any part of a living plant be burned in the air. Even a bit of straw kindled in the flame of a candle (fig. 6), and allowed to burn, will leave a sensible quantity of ash behind. All plants therefore, and all parts of plants, besides water and carbon, contain also a sensible proportion of mineral inorganic matter which is incombustible, and which remains unconsumed when they are burned in the air.

Fig. 6.



The carbon of the plant is chiefly derived from the air, the water and the mineral matter wholly from the soil in which it grows. Thus the plant we rear has close chemical relations with the air we breathe, with the water we drink, and with the soil we cultivate. I shall briefly illustrate these several relations in their order.

First, The plant is in contact with the air, through its leaves. The surface of the leaf is studded over with numerous minute pores or mouths (*stomata*), through which gases and watery vapour are continually entering or escaping, so long as the plant lives. In the daytime, and especially during sunshine, they absorb carbonic acid gas, and they give off

oxygen. During the night this process is apparently, and to a slight degree, reversed—they then absorb oxygen and give off carbonic acid. It must be borne in mind, however, that this is true only of the green parts of the plant; for the other parts, such as the flowers, even in daytime, absorb oxygen and give out carbonic acid—the amount, however, being trifling.

We have already seen that carbonic acid consists of carbon and oxygen.[1] It is from the large excess of this gas which plants absorb during the day that the greater part of the carbon they contain is usually derived.

The number and activity of the little mouths which stud the leaf are very wonderful. On a single square inch of the leaf of the common lilac as many as 120,000 have been counted; and the rapidity with which they act is so great, that a thin current of air passing over the leaves of an actively-growing plant is almost immediately deprived by them of the carbonic acid it contains.

The gas thus absorbed enters into the circulation of the plant, and there undergoes a series of chemical changes,[2] which it is very difficult to follow. The result, however, we know to be, that its carbon becomes the principal ingredient of the starch, sugar, oil, woody fibre, &c., which build up the plant, while its oxygen is given off to maintain the purity of the air.

These pores of the leaf absorb also other gaseous substances in smaller quantity—such as ammonia, when it happens to approach them; but it is doubtful whether they absorb watery vapour, even when previous heat or drought has dried the plant, and made the leaves droop soft and flaccid. Vapour or falling water moistens the soil and thus supplies their want of fluid, while it washes also the dusty surface of the leaves, and clears their many mouths, so that with fresh vigour they can suck in new nourishment from the surrounding air.

The green bark of the young twig is perforated with pores like the green leaf, and acts upon the air in a similar way; but as it hardens and gets old the pores become obliterated, and it ceases to aid the leaves in absorbing carbonic acid, or in giving off oxygen to the atmosphere.

Secondly, The water which fills the cells and vessels of the

[1] See "The Air we Breathe."

[2] For the part performed by the green-colouring matter of leaves in these changes, see "The Colours we Admire."

plant is principally, if not wholly, sucked up by the roots from the earth in which it grows. These roots, as I have said, are only downward expansions of the stem. At the surface of the ground they exhibit a bark without and a pith within the woody portion. But as they descend, these several parts disappear, and graduate into a porous, uniform, spongy mass, which forms the ends of the fibrous rootlets. Upon the surface of these rootlets, especially when young, the microscope enables us to perceive numerous minute hairs which thrust themselves laterally among the particles of the soil. Through these root-hairs the plant draws from the earth the supplies of water it constantly requires, and which it so copiously pours out from its leaves into the air. With this water it likewise takes up in solution the mineral or saline matters which it needs.

How interesting it is to reflect on the minuteness of the organs by which the largest plants are fed and sustained! Microscopic apertures in the leaf suck in gaseous food from the air; the surfaces of microscopic hairs suck a liquid food from the soil. We are accustomed to admire, with natural and just astonishment, how huge rocky reefs, hundreds of miles in length, can be built up by the conjoined labours of myriads of minute zoophytes labouring together on the surface of a coral rock; but it is not less wonderful that, by the ceaseless working of similar microscopic agencies in leaf and root, the substance of vast forests should be built up, and made to grow before our eyes. It is more wonderful, in fact; for whereas in the one case the chief result is that dead matter extracted from the sea is transformed into a dead rock, in the other the lifeless matters of the earth and air are converted by these minute plant-builders into living forms, lifting their heads aloft to the sky, waving with every wind that blows, and beautifying whole continents with the varying verdure of their ever-changing leaves.

The water which the roots absorb, after it has entered the plant, serves many important physiological and chemical purposes. It fills up mechanically and distends the numerous vessels; it mechanically dissolves, and carries with it, as it ascends and descends, the various substances which are contained in the sap; it moistens and gives flexibility to all the parts of the plant, and, by evaporation from the leaves, keeps

it comparatively cool, even in the sunniest weather. But its chemical agencies, though less immediately sensible, are equally important. It combines with the carbon, which the leaf brings in from the air, and forms woody fibre, sugar, starch, and gum—all of which consist of carbon and water only; and if we accept the current doctrine of the direct or indirect decomposition of water taking place within the plant, the water will serve as a constant and ready storehouse, also, for the supply of oxygen and hydrogen, which are required, now here and now there, for the formation of the numerous different substances which, in smaller quantity than starch or woody fibre, are met with in the different parts of the plant. Many diverse chemical changes are every instant going on within the substance of a large and quickly-growing tree, and in nearly all these the constituent elements of water—its oxygen and hydrogen—play a constant part. The explanation of the nature of these products of vegetable activity fills up already a large division of our modern treatises on organic chemistry.

Thirdly, To the soil the plant is perceived, even by the least instructed, to have the closest relations. To the most instructed these relations every day appear more interesting and wonderful.

I have already adverted, in the preceding chapter, to what may be called the physiological habits of plants, which incline them to grow upon soils which are more or less wet, more or less sandy and porous, and more or less heavy in the agricultural sense. Owing to these habits, every variety of soil, in every climate, supports its own vegetable tribes. Thus, of the five thousand flowering plants of central Europe, only three hundred grow on peaty soils, and these are chiefly rushes and sedges. In the native forests of northern Europe and America, the unlettered explorer hails the gleam of the broad-leaved trees glittering in the sun, amid the ocean of solemn pines, as a symptom of good land on which he may profitably settle. And so, many a rough peasant at home knows that wheat and beans affect clay soils,—the humblest North German, that rye alone and the potato are suited to his blowing sands,—and the Chinese peasant, that warm sloping banks of light land are fittest for his tea plant, and stiff, wet, impervious clays for his rice. Nicer differences do not pass

unnoticed by the least observant. The English farmer knows that barley from heavy clays will not malt well though it will feed excellent pork. The Scotch hind living in a bothy knows that oats from strong land will give him a more nourishing meal for his daily brose. The poorest Irish peasant knows that his most beloved laughing mealy potato will give him a wet and waxy crop on a stiff clay instead of on a light and open soil. And the Norman peasant can distinguish by his practised taste whether the cider he is drinking has been produced from a chalk soil, a sand, or a clay. Even the negro of Alabama is aware that dry open alluvials, and porous uplands, suit best the cotton he cultivates; and the degraded slave of Pernambuco, that the cocoa grows only on the sandy soils of the coast—just as in his native West Africa the oil-palms flourish on the moist sea-sands that skirt the shore, and the mangroves, where muddy shallows are daily deserted by the retiring tide.

Hundreds of square miles of grass-prairies and sage-prairies exist in the central parts of the North American continent. The rough grasses are buffalo-grass, and gramoma or mezquite; the wild sage of these deserts is an Artemisia.

But these relations of plants become more conspicuous when we examine somewhat closely the influence of artificial changes in the soil upon the kind, the growth, and the character or appearance of the plants which spring up or are sown upon it.

Thus when a peaty soil is drained, the heaths disappear, and a soft woolly grass (*Holcus lanatus*) overspreads its surface. A wet clay is laid dry, and the rushes and water-loving plants are succeeded by sweet and nutritious herbage. Lime is applied, and sorrel and sour grasses are banished from the old pasture; and corn then ripens and fills the ear where formerly it languished and yielded scanty returns of unhealthy grain. Crushed bones are strewed over a meadow, and abundant milk and cheese show how the eatage of cattle has been improved—or they are drilled into the ploughed land, and luxuriant root-crops exhibit their ameliorating effect. Or guano, or the droppings of cattle, or the liquid of the farm-yard, or nitrate of soda, are spread upon the scanty pasture, and straightway the humble daisy and the worthless moss—symbols of poverty—disappear, and rejoicing crops of most

fragrant hay prove the close connection of the plant with the soil on which it grows. Or again, gypsum or a potash manure such as the *kainite* of Stassfurth is scattered upon the meadow, when the nutritious clovers and vetches are strengthened and become abundant.

The plant derives, as I have elsewhere said, the whole of its mineral matter from the soil, and some portion also of that which forms its combustible part. A naturally fertile soil contains all these things in sufficient abundance, and can readily supply them to the craving roots. The waters which moisten the soil dissolve them, and the minute hairs I have spoken of suck them up, and send them through the roots and stem to the several parts of the plant. Manures supply to the soil those necessary forms of vegetable food in which it is deficient; and the effects which follow from the addition of manures show how closely the welfare of the plant is connected with the chemical composition of the soil. The raw materials also, which it takes up by the root, like those which enter by the leaf, undergo within the plant numerous successive chemical changes, by which they are converted into the substance of the plant itself, and are fitted for those after purposes, in reference to animal life, which, in the economy of nature, the plant fulfils.

Among the pleasing proofs of such chemical changes taking place within the plant, I may mention the effects upon the colour of their flowers, which follow from the application of certain substances to the roots of plants. Charcoal-powder darkens the flowers of the dahlia, the rose, the petunia, &c.; peat changes the red of the hydrangea to blue; while many chemical salts in minute proportions modify or enrich the colours of garden flowers. Carbonate of soda reddens ornamental hyacinths, and superphosphate of lime alters in various ways the hue or bloom of other cultivated plants. As the dyer prepares the chemical ingredients of the baths into which his stuffs are to be dipped, and varies the one with the colour he is to give to the other—so within the plant the substances applied to the root are chemically prepared and mixed, so as to produce the new colour imparted by their means to the petals of the flower.

But such effects of chemical art are far inferior both in interest and importance to those which protracted nursing have

produced upon our commonly cultivated plants. The large and juicy Altringham carrot is only the woody spindly root of the wild carrot (*Daucus Carota*), common enough on our south coast, luxuriously fed. Our cabbages, cauliflowers, kohl-rabis, and turnips, in all their varieties, spring from one or more species of Brassica, which in their natural state have poor woody bitter stems and leaves, and useless woody and spindle-shaped roots. Our cultivated potato, with all its varieties, springs from the tiny and bitter root of the wild potato, which has its native home on the woody sea-shores of Chili; and our apples, plums, grapes, and other prized fruits, from well-known wild and little-esteemed progenitors. Our kitchen-gardens are full of such vegetable transformations, of which the seakale, the beet, and the asparagus are notable examples.

It is so likewise with our corn-plants. On the French and Italian shores of the Mediterranean grows a wild neglected grass known by the name of *Ægilops ovata.* Transplanted to the garden or to the field, and differently fed, its seed enlarges, and after a few years' cultivation, changes into a grain resembling wheat. It is not proved that the *Ægilops ovata* was the origin of our wheat. But this and other cereals, oats and barley, and rye and maize, in all their varieties, as well as the numerous forms of the eastern dhurra, rice and millet, and of the less-known quinoa of Upper Chili and Peru, doubtless sprang by natural and artificial selection and improvement from wild plants of little nutritive value. It is the new chemical and physical conditions in which the plants are placed, which mainly cause the more abundant introduction of certain forms of food into their circulation, and the more full development, in consequence, either of the whole plant, or of some of its more useful parts.

It is with unconscious reference to these improved conditions that certain wild and useless plants attach themselves to and appear affectionately to linger in the footsteps of man. They follow him in his migrations from place to place—advance with him, like the creeping and sow thistles, as he hews his way through primeval forests—reappear constantly on his manure-heaps—spring up, like the common dock, about his stables and barns—occupy, like the common plantain, the roadsides and ditches he makes—or linger, like the nettle,

over the unseen ruins of his dwelling, to mark where his abode has formerly been. Thus, with the European settler, European weeds in hundreds have spread over all Northern America,[1] and are readily recognised as familiar things, speaking to them of a far-off home, by the emigrants to the shores of Australia and New Zealand. We cannot say that all these have followed the European. Many of them have only accompanied him, and, like himself, taken root in what has proved a favourable soil. But those which cling closest to his footsteps, which go only where he goes—which, like his cat or his dog, are in a sense domesticated—these attend upon him, because near his dwelling the appropriate chemical food is found, which best ministers to the wants of their growing parts.

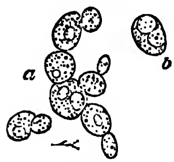
How singularly dependent the plant is upon the chemical nature of the medium in which it is placed, is beautifully illustrated by the manner in which the humblest forms of vegetation are seen to grow and propagate. The yeast with which we raise our bread is a minute plant belonging to the protophytes or simplest and smallest of vegetable organisms. If we make a thick syrup of cane-sugar, and strew a few cells of this yeast upon it, they will begin to grow and propagate, will cause minute bubbles of gas to rise, and the whole syrup gradually to ferment. But if, instead of a syrup of sugar, we take a thick solution of gum, the yeast will produce no sensible effect; it will neither propagate nor cause a fermentation. In the one case the minute plant has met with a somewhat congenial food; in the other it has found nothing which it can affect and on which it can live and grow.

But in the juice of ripe grapes it has a more favourable medium still. "If we filter this juice, we obtain a clear, transparent liquid. Within half an hour this liquid begins to grow, first cloudy, and afterwards thick, to give off bubbles of gas, or to ferment, and in three hours a greyish-yellow layer of yeast has already collected on its surface. In the heat of the fermentation the plants are produced by millions—a single cubic inch of such yeast, free from adhering water, containing eleven hundred and fifty-two millions of the minute organisms." The annexed woodcut (fig. 7) shows the appearance of the yeast plant, as seen under the microscope when the

[1] See the author's Notes on North America, vol. i. p. 109.

propagation is in full activity. The cells or globules are shown magnified 400 diameters.

Fig. 7.



The Yeast plant.

The juice of the grape thus readily propagates the spores of yeast which accidentally reach it, because it contains the food which, in kind, in form, and in quantity, is best suited to its rapid growth.[1]

And so it is with larger plants in the soil. They grow well and healthily if it contains the food in which they delight. They droop if such food is absent, and again burst into joyful life when we supply by art those necessary ingredients in which the soil is deficient.

But the special chemical changes that go on within the

[1] Whence come the seeds, spores, or germs of this yeast plant, which propagates itself with such wonderful rapidity? Do they exist already in the juice of the living grape? Do they cling to the exterior of the fruit, and only become mixed with the juice when it is in the wine-press, or do they float perpetually in the air, ready to germinate and multiply wherever they obtain a favourable opportunity? Whichever way they come, it would be too slow a process to wait for the natural appearance of these plants in the worts of the brewer and distiller. In these manufactories, therefore, it is customary to add a little yeast to the liquor as soon as it is considered ready for the fermentation. Then, as in the case of the grape, the growth and propagation of the plant proceed with astonishing rapidity, and large quantities of yeast are produced. This yeast in many distilleries forms an important *by-product* of the manufactory, and is collected and sold under the name of dry yeast, for the use of the private brewer and the baker. When this is done, the process adopted is nearly as follows: Crushed rye is mashed with the proper quantity of barley malt, and the wort, when made, cooled to the proper temperature. For every hundred pounds of the crushed grain, there are now added half a pound of carbonate of soda, and six ounces of oil of vitriol (sulphuric acid) diluted with much water, and the wort is then brought into fermentation by the addition of yeast. From the strongly fermenting liquid the yeast is skimmed off, and strained through a hair sieve into cold water, through which it is allowed to settle. It is afterwards washed with one or two waters, and finally pressed in cloth bags till it has the consistence of dough. It has a pleasant fruity smell, and in a cool place may be kept for two or three weeks. It then passes into a putrefying decomposition, acquires the odour of decaying cheese, and, like decaying cheese, has now the property of changing sugar into *lactic acid*, instead of into alcohol, as before. A hundred pounds of crushed grain will yield six to eight pounds of the pressed yeast. It is made largely at Rotterdam, and is imported thence to this country through Hull. In 1876 more than 8000 tons arrived here.

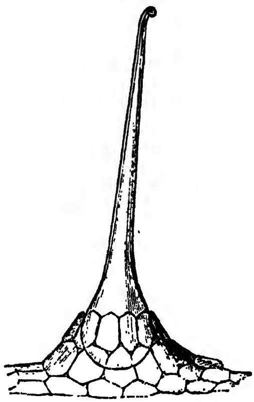
plant, could we follow them, would appear not less wonderful than the rapid production of entire microscopic vegetables from the raw food contained in the juice of the grape. It is as yet altogether incomprehensible, even to the most refined physiological chemistry, how, from the same food taken in from the air, and from generally similar food drawn up from the soil, different plants, and different parts of plants, should be able to extract or produce substances so very different from each other in composition and in all their properties. From the seed-vessels of one (the poppy), we collect a juice which dries up into our commercial opium; from the bark of another (cinchona) we extract the quinine with which we assuage the raging fever; from the leaves of others, like those of hemlock and tobacco, we distil deadly poisons, often of rare value for their medicinal uses. The flowers and leaves and seeds of some yield volatile oils, which we delight in for their odours and their aromatic qualities; the seeds of others give fixed oils, which are prized for the table or for use in the arts. The wood of some is rich in valuable dyes, while from that of others exude turpentines and resins of varied degrees of worth—from the cheap rosin of the tinsmith and soap-maker to the costlier myrrh and aloes and benzoin which millions still burn, as acceptable incense, before the altars of their gods. The slender stems of others furnish the raw material out of which ropes, linen, and lawn are made. The bark of the lace-tree yields a delicate network of woody fibre of great utility; and even from a nettle—the China-grass—a kind of flax is produced, which is made into handkerchiefs.

These, and a thousand other similar facts, tell us how wonderfully varied are the changes which the same original forms of matter undergo in the interior of living plants. Indeed, whether we regard the vegetable as a whole or examine its minutest parts, we find equal evidence of the same diversity of changes, and of the same production, in comparatively minute quantities, of very different, yet often very characteristic forms of matter.

Thus, looking at a large tree as a whole, we are charmed with the brilliant green foliage which invests it when summer has come, and to which the landscape owes half its charms. Yet chemistry tells us that all this effect of colour is produced by a few ounces of colouring matter distributed

evenly over its thousands of leaves. The microscope tells us something more, revealing as it does that the liquid sap of the greenest plant is not itself green. The cells which seem green to the unassisted eye, are seen, under the microscope, to contain minute granules of a green substance called chlorophyll, embedded in a layer of formative matter, or protoplasm, lining their walls.

Fig. 8.



The acid is driven from the prickly hair, on its point being broken, by the elastic cells at the base.

The same microscope, aided by chemistry, explains how the nettle acts upon our hands, assuring us that the pain it causes, when allowed to pierce the skin, arises from a reservoir of a peculiar acid (the formic acid), which, like the poison of the serpent's tooth, is squeezed into the wound which the spikelet makes.

The characteristic property of the minute nettle-hair, and the peculiar charm of the wide landscape, are equally dependent upon the production in living plants of special forms of matter in comparatively minute proportions—upon hereditary tendencies towards definite lines of chemical activity transmitted by the most minute seed or bud from generation to generation.

The tuber of the potato, the ripening apple, and the growing twig, present us with another illustration of special chemical changes proceeding continuously in the plant, and with a definite reference to a specific and useful end. The unripe potato, when taken from the earth, withers and shrivels, becomes unsightly to the eye, and vapid to the taste; the unripe apple shrinks in, refuses to retain its natural dimensions, and cannot be kept for any length of time, while the unripe twig perishes amidst the chills of winter, and remains black and dead when the green buds of spring were expected to enliven its surface. These effects are the consequence of the thin bark which covers potato, apple, and twig alike, not having attained its matured composition. While unripe, this coating is porous and pervious to water, so that, when removed from the parent plant, tuber, fruit,

and twig all give off water by evaporation to the air, and thus shrivel and shrink in as I have described. But when ripe, this porous covering has become chemically changed into a thin impervious coating of *cork*, through which water can scarcely pass, and by which, therefore, it is confined within for months together. It is this corky layer which enables the potato to keep the winter through; the winter pear and winter apple to be brought to table in spring of their full natural dimensions; and the ripened twig to retain its sap undried, and to feed the young bud when the April sun first wakens it from its winter's sleep.

Nor are the general purposes for which the entire plant lives, and is the theatre, so to speak, of so many changes, to be properly, I may say at all appreciated, without the assistance of chemical research.

It is true that every one can recognise in the natural herbage and the wild forest the ornaments of the landscape; in the thousand odours they distil, and in the varied hues and forms with which they sprinkle the surface, the most agreeable and refined ministers to our sensuous pleasures. And in these things we unquestionably see some of the true purposes served by vegetation in the economy of nature. But they are subsidiary purposes—which they serve by the way, as it were, while labouring to fulfil their true and greater vocation.

This vocation may be viewed in two aspects: *first*, as regards dead nature; and, *secondly*, as regards living things.

First, In its relation to dead nature, the plant serves, while living, to purify the air we breathe. Its green parts continually absorb carbonic acid and give off oxygen gas during the day, and thus become a chief instrument in maintaining the normal condition of the atmosphere. It renders the air more fit for the support of animal life, both by removing that which is noxious (the carbonic acid), and by pouring into it that which is salutary (the oxygen) to animal health and life. And then, when it dies, it either covers the earth with a vegetable mould, which favours the growth of new generations of plants, or it accumulates into beds of peat or mineral coal, by which man is long after to be warmed, and the arts of life promoted. But in either case it only lingers for a while in these less sightly mineral forms. It gradually assumes again the gase-

ous state, and whether it is allowed naturally to decay, or is burned in the fire, ultimately rises again into the air in the form of carbonic acid. By this means, in part, vegetation is perpetuated upon the globe, and the natural composition of the atmosphere, as regards the proportion of the carbonic acid gas, is permanently maintained. And,

Secondly, As regards living animals, we all know and feel that plants are necessary to our daily life. Utterly dry up and banish vegetation from a region, and nearly every sensible form of animal life forthwith disappears. But how do plants feed us? And by what virtues in their several parts can the ox thrive on the straw, while man can live only on the grain? How can human life be permanently sustained on the nut and fruit of the tree? How can the leaves and twigs of the thick forest support the lordly elephant?

As to dead nature, the plant serves a subsidiary purpose in covering and adorning it—so to living nature, to man especially, it serves a similar subsidiary purpose in producing the numerous remarkable products, to which I have already alluded as being useful in medicine and the arts, and as ministering to the luxuries and comfort of civilised life. In the production of these we recognise a destined and benevolent purpose served by the general vegetation of the globe, in reference to living things. But this purpose is only secondary, and, as it were, ornamental. The main object of the plant, in its relations to the animal, is to feed it. This it does with various forms of vegetable matter in different climes and countries, and it provides for each herbivorous and carnivorous race those peculiar forms on which it best loves, because it is best fitted, to feed. It is so with man. His vegetable food varies with the part of the world in which he is situated; yet upon all the varieties with which different climates furnish him, he discovers the means continuously to sustain himself.

Of what chemical substances do these different forms of nutritious food consist? What do they possess in common? In what do they differ? Why do some of them, weight for weight, sustain the body more completely or for a longer time than others? Why do they affect the dispositions of those who consume them—not only the constitution of individuals, but the habits, temperament, and character of whole

nations? Why do we choose to mix the forms of vegetable food we consume—whence come the fashions of universal cookery—whence the peculiarities of national dishes?

What a host of curious chemical inquiries spring up in connection with the plant we rear, regarded as the main sustenance or staff of common life! I shall consider some of them in the following chapter.

CHAPTER V.

THE BREAD WE EAT.

The grain of wheat.—Bran and flour.—Separation of flour into starch and gluten.—Fermenting of dough.—Baking of bread.—New and stale bread.—Proportion of water in flour and in bread.—Composition of bread.—Bran richer in gluten. —Comparative composition. — Wheaten and rye bread compared.—Oatmeal and Indian-corn meal.—Composition of rice.—Buckwheat, quinoa, Guinea corn, and dhurra. —Composition of beans, peas, and lupins.—The sago-palm, and the seeds of the araucaria.—The fruits of the banana, the date-palm, the fig-tree, and the bread-fruit tree.—Water contained in fruits and roots.—The turnip, carrot, and potato.—The composition of rice, the potato, and the plantain compared.—Deformity among the eaters of these three vegetables.—The Siberian lily.—The use of leaves as food.—The cabbage very nutritious.—Natural tendency of man to adjust the constituents of his food.—Irish kol-cannon.—Starvation upon arrowroot and tapioca.—General characters of a nutritious diet.—National and individual influence of diet.

THE bread we eat I take as the type of our vegetable food. On such food of various kinds, and eaten in various forms, man and animals are sustained in all parts of the globe. The study of our common wheaten bread will give us the key to the composition and known usefulness of them all.

1°. WHEAT.—When the grain of wheat is crushed between the stones of the mill, and is then sifted, it is separated into at least two parts—the bran and the flour. The bran consists chiefly of the outside, harder part of the grain, which does not crush so readily, and when it does crush, darkens the colour of the flour. It is therefore generally sifted out by the miller, and is used for feeding horses, oxen, and pigs. Whole meal and brown meal contain both bran and flour, and are much used for making brown bread.

If the flour be mixed with a quantity of water sufficient to moisten it thoroughly, the particles cohere and form a smooth, elastic, and tenacious dough, which admits of being drawn out to some extent, and of being moulded into a variety of forms. If this dough be placed upon a sieve or on a piece of muslin, and worked with the hand under a stream of water (fig. 9), as long as the water passes through milky, there will remain at last upon the sieve a white sticky substance very much resembling bird-lime. This is the substance which gives its tenacity to the dough. From its glutinous character it has obtained among chemists the name of gluten. When the milky water has become clear by standing, a white powder will be found at the bottom of the vessel, which is common wheaten starch. Thus the flour of wheat contains two principal substances, gluten and starch. Of the former, every 100 lb. of fine English flour contain about 10 lb., and of the latter about 70 lb.

Fig. 9.

Mode of separating the Gluten from the Starch of Wheat.

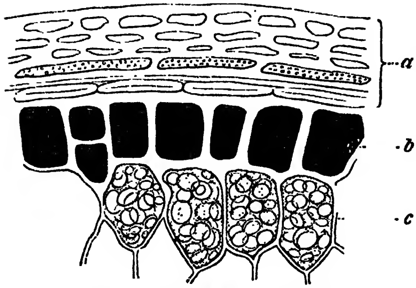
The way in which the bran, the gluten, and the starch are respectively distributed throughout the body of the seeds of our corn plants is shown in the following section (fig. 10) of a fragment of a grain of wheat when fully ripe.

In the figure, *a* represents the several seed and fruit coats of the grain; *b* a layer of cells containing much gluten. These together form the bran. *c* represents the cellular tissue of the albumen,[1] consisting of large hexagonal cells, which contain granules of starch.

[1] The reader must not confound this word *albumen*, used by botanists to denote the white inner part of the seed, with the same word used in chemistry as the name of the characteristic constituent of the *white of the egg*.

Figure 11 exhibits one of the cells of the albumen more highly magnified, and shows how the grains of starch are disposed in it. The small figures to the right are grains of starch still more highly magnified. Their natural size varies from a ten-thousandth to a six-hundredth of an inch.

Fig. 10.

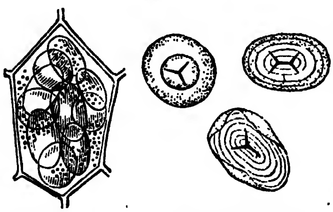


Section of part of a Wheat-grain.

The outer coating contains only 4 or 5 per cent of gluten, the inner coating from 14 to 20 per cent. All this is separated in the bran. Throughout the mass of the grain around and within the albumen-cells the gluten is diffused everywhere among the grains of starch.

When a little yeast is added to the flour before or while it is being mixed with water into a dough, and the dough is then placed for an hour or two in a warm atmosphere, it begins to *rise*—it ferments, that is, and swells or increases in bulk. Bubbles of gas (carbonic acid gas) are disengaged in the interior of the dough, which is thereby rendered light and porous. If it be now put into a hot oven, the fermentation and swelling are at first increased by the high temperature; but when the whole has been heated nearly to the temperature of boiling water, the fermentation is suddenly arrested, and the mass is fixed by the after-baking in the form it has then attained.[1]

Fig. 11.



Single cell. Granules of Starch.

It is now newly-baked bread, and if it be cut across it will appear light and spongy, being regularly sprinkled over with little cavities, which were produced in the soft dough

[1] The formation of hard crusts on the loaf may be prevented by rubbing a little melted lard or by sprinkling a little milk over it after it is shaped, and before it is set down to rise, or by baking it in a covered tin.

by the bubbles of gas given off during the fermentation. This fermentation is the consequence of a peculiar action which yeast exercises upon moist flour. It first changes a part of the starch of the flour into sugar, and then converts this sugar into alcohol and carbonic acid, in the same way as it does when it is added to the worts of the brewer or the distiller. As the gas cannot escape from the glutinous dough, it collects within it in bubbles, and makes it swell, till the heat of the oven kills the yeast plant, or so changes or fixes its active ingredients as to cause the fermentation to cease. The alcohol escapes, for the most part, during the baking of the loaf, and is dissipated in the oven, but a little remains in the bread, which has been found to contain about two parts of alcohol in a thousand.

New-baked bread possesses a peculiar softness and tenacity, and though generally considered less digestible, is a favourite with many. After a day or two it loses this softness, becomes free and crumbly, and apparently drier. In common language, the bread becomes stale, or it is stale bread. This change does not arise wholly from the bread becoming actually drier by the gradual loss of water. Stale bread contains nearly the same proportion of water as new bread after it has become completely cold. The change is in the internal arrangement of the molecules of the bread. A proof of this is, that if we put a stale loaf into a closely-covered tin, expose it for half an hour or an hour to a heat not exceeding that of boiling water, and then remove the tin, and allow it to cool, the loaf when taken out will be restored in appearance and properties to the state of new bread.

The quantity of water which well-baked wheaten bread contains, amounts on an average to about 40 per cent. The bread we eat, therefore, is more than one-third water.

The flour of wheat and of other kinds of grain contains water naturally, but it absorbs much more during the process of conversion into bread. 100 lb. of fine wheaten flour take up 45 lb., or nearly half their weight of water, and give 145 lb. of bread. Thus, 100 lb. of English flour and 145 lb. of bread contain respectively—

	The flour contains	The bread contains
Dry flour,	85	85
Natural water,	15	15
Water added,	...	45
	100 lb.	145 lb.

One of the reasons why bread retains so much water is, that during the baking a portion of the starch is converted into a kind of gum called dextrine, which holds water more strongly than starch does; a second is, that the gluten of flour, when once thoroughly wet, is very difficult to dry again, and that it forms a tenacious coating round every little hollow cell in the bread, which coating does not readily allow the gas contained in the cell to escape, or the water to dry up and pass off in vapour; and a third reason is, that the dry crust which forms round the bread in baking is nearly impervious to water, and, like the skin of a potato which we bake in the oven or in the hot cinders, prevents the moisture within from escaping.

The proportions of water, gluten, and starch or gum, in well-baked wheaten bread, are nearly as follows:—

Water,	40
Gluten,	7
Starch, sugar, and gum,	51
Salt, and other mineral matters,	2
	100

The bran or husk of wheat, which is separated from the fine flour in the mill, and is often condemned to humbler uses, is somewhat more nutritious, so far as concerns flesh-forming and bone-forming constituents, than either the grain as a whole, or the whiter part of the flour. The nutritive quality of any variety of grain depends much upon the proportion of gluten which it contains; and the proportions of this in the whole grain, the bran, and the fine flour respectively, of the same sample of wheat, are very nearly as follows:—

Whole grain,	12 per cent.
Whole bran (outer and inner skins),	14 to 18 ,,
Fine flour,	10 ,,

If the grain, as a whole, contain more than 12 per cent of gluten, the bran and the flour will also contain more than is above represented, and in a like proportion. The *whole meal* obtained by simply grinding the grain is equally nutritious with the grain itself. By sifting out the bran we render the meal less nutritious, weight for weight; and when we consider that the bran is rarely less than one-fifth of the whole weight of the grain, we must see that the total separation of

the covering of the grain causes much waste of wholesome human food. Bread made from the whole-meal is therefore more nutritious; and as many persons find it also a more salutary food than white bread, it ought to be more generally preferred and used. Another reason for supposing it to be more nutritious is derived from the discovery that the bran of wheat, besides the nutritious quality it derives from the large percentage of gluten it contains, possesses also the property of dissolving the flour or bread with which it is mixed, and of rendering it more easily digestible in the stomach. It contains a peculiar species of ferment, which, in the presence of water, and aided by the heat of the oven in baking, and of the stomach during digestion, gradually converts the starch of the bread into sugar. To this property of bran, as well as to the nourishment it yields, is to be ascribed a portion of those wholesome qualities which many persons have recognised in whole-meal bread. Like oatmeal, it is a somewhat laxative food; and, moreover, it must not be forgotten, that the roughness of whole-meal bread causes it to be hurried through the alimentary canal before all its goodness has been extracted and absorbed.

The woodcut and explanation given on p. 70 show that the gluten of the husk occurs chiefly in the inner coverings of the grain. Hence the outer covering may be removed without sensible loss of nutriment, leaving the remainder both more nutritious than before, weight for weight, and also more digestible than when the thin outer covering is left upon the corn. This removal of the outer fibrous coat involves the loss of about 2 lb. in 100 of grain. It may be accomplished by moistening the grain and rubbing it, or by a special process of milling known as decortication.

It is also a point of some interest that the small or tail corn, which the farmer separates before bringing his grain to market, and usually grinds for his own use, is richer in gluten than the plump full-grown grain, and is therefore more nutritious.

The amount of wheat annually consumed per head in the United Kingdom has been gradually increasing—

In 1848 it amounted to	311 lb.
In 1868 „	335 „
In 1877 „	341 „.

Unfortunately, both flour and bread are frequently adulterated with injurious substances. Some flour seized at a mill in Apperley Bridge, Yorkshire, contained 1 part of alum in 240 of wheat. Of 20 samples of bread bought in the east of London in 1871, Mr Muter found 7 containing alum, and 1 sulphate of copper. He gives the following percentages as representing the general condition of London bread at that time: Pure bread, 52 per cent; alumed, 23 per cent; coppered, 15 per cent.

2°. Barley and Rye resemble the grain of wheat very much in composition and nutritive quality. They differ from it somewhat in flavour and colour, and do not make so fair and spongy a bread. They are not generally preferred, therefore, in countries where wheat and other grains thrive and ripen. In composition and nutritive quality wheaten and rye bread very closely resemble each other; and except as concerns our taste, it is a matter of indifference whether we live on the one or the other. Rye bread possesses one quality which is in some respects a valuable one: it retains its freshness and moisture for a longer time than wheaten bread, and can be kept for months without becoming hard, dry, or unpalatable. This arises principally from certain peculiar properties possessed by the variety of gluten which exists in the grain of rye. On the other hand, rye is peculiarly liable to the attacks of a fungus causing the "ergot." On the Continent, rye gangrene of the limbs, induced by eating bread made from the ergoted grain, has proved fatal.

3°. Indian Corn or Maize, the "corn" of the United States, also resembles wheat in composition and nutritive quality. Its grain has a peculiar flinty hardness, and its flour, usually known as Indian meal, a flavour which in this country is not at first relished. It does not bake into the same light spongy loaves as wheaten flour, but is excellent in the form of cakes. The chief peculiarity in its composition is, that it contains more oil or fat than any of our common grains, except the oat. This oil sometimes amounts to as much as 9 lb. in 100, and is supposed to impart to Indian corn a peculiar fattening quality, by those who conclude that all the fat eaten makes fat, and who would order a nursing mother to drink milk. But it is not fat-eaters who are the fattest; nor is all the fat in the body formed from fat in the food. Maize soaked

in water for some time, then ground into pulp, yields the material of the Mexican cakes called *tortillas*. The Mexican women are often employed six hours a-day over this work.

4°. Oats are a favourite food in our island for horses, and in Scotland especially are much esteemed as an agreeable, nutritious, and wholesome food for man. The meal of this grain is distinguished for its richness in gluten, and for containing more fatty matter than any other of our cereal grains. To these two circumstances it owes its eminently nutritious and wholesome character. The average relative proportions of gluten, fat, and starch contained in fine wheaten flour, in Scotch oatmeal, and in Indian-corn meal, are represented by the following numbers :—

	English fine wheaten flour.	Bran of English wheat.	Scotch oatmeal.	Indian-corn meal.
Water, . .	13	14	5	15
Gluten, . .	10	16	16	9
Fat, . . .	1	4	10	5
Starch, &c., .	74	43	63	64
Fibre, . .	1	17	4	5
Ash, . . .	1	6	2	2
	100	100	100	100

The large proportion of fatty matter contained in Indian corn is supposed to adapt it well for fattening animals; it certainly makes it more grateful to the alimentary canal, and therefore more wholesome. I have inserted in the above table a column showing the average composition of the bran of English wheat, for the purpose of showing, *first*, how large a proportion of fat it also contains, compared with fine wheaten flour; and, *secondly*, the remarkable similarity in composition, in some respects, which exists between the bran of wheat and the meal of the oat.

Owing to a peculiar quality of the gluten which the oat contains, the meal of this grain does not admit of being baked into a light fermented spongy bread. It has been alleged against oatmeal, that when used as the sole food, without milk or other animal diet, it produces heat and irritability of the skin, aggravates skin diseases, and sometimes occasions boils, in the same way as salt meat tends to produce scurvy. Dr

Pereira, a high authority, states that this charge has been made without just grounds. At all events, it must be very rarely that circumstances render necessary for any length of time such an exclusive consumption of oatmeal.

5°. Rice is remarkable chiefly for the comparatively small proportion of gluten it contains. This does not exceed seven or eight per cent—less than half the quantity contained in oatmeal. In rice countries, it has often been noticed that the natives devour what to us appear enormous quantities of the grain, and this circumstance is ascribed to the small proportion it contains of the highly nutritive and necessary gluten. Rice contains also little fat, and hence it is less laxative than the other cereal grains, or rather it possesses something of a binding quality. It has been observed that, when substituted for potatoes in some of our workhouses—in consequence of the failure of the potato—this grain has after a few months produced scurvy. This may have been partly owing to the effects of sudden change of diet, and partly to the deficiency in mineral matters characteristic of this grain. Still it suggests, as many other facts do, the utility and wholesomeness of a mixed food. Rice is, however, an easily digested food. Its composition is—

Water,	14½
Fibrin,	7½
Starch,	76
Fat,	½
Fibre,	1
Ash,	½
	100

6°. Buckwheat flour is about as nutritious as English wheaten flour, and makes excellent cakes, which, when eaten hot with maple-honey, in the backwoods of America, are really delicious.

7°. Quinoa.—A variety of grain scarcely known in this country is the quinoa (fig. 12), a small roundish seed which is extensively cultivated and consumed on the high tablelands of Chili and Peru. There are two varieties of it—the sweet and the bitter—which grow at elevations rising to 13,000 feet above the level of the sea, where both rye and barley refuse to ripen. It is still the principal food of the many thousands of people who occupy these high lands, and, before the introduction of European grains by the

Spaniards, is said to have formed the chief nourishment of the Peruvian nation. It is very nutritious, and in its composition approaches very nearly to that of oatmeal, but contains rather less fat. A grain so nutritious as this is a very precious gift to the inhabitants of the elevated regions of the Andes. Without it, those lofty plains could only be runs for cattle, like the summer pastures among the valleys on the Alps.

Fig. 12.

Chenopodium Quinoa—
The Quinoa plant.
Scale, 1 inch to 2 feet.

Fig. 13.

Sorghum vulgare—One of the plants yielding Dhurra or Indian Millet.
Scale, 1 inch to 2 feet.

8°. Guinea Corn, a small grain, used to some extent in the West Indies, is a little less nutritious than ordinary English wheat.

9°. Dari, Dhurra or Dhoora (fig. 13), a small kind of grain much cultivated and extensively consumed in India, Egypt, and the interior of Africa. On the alluvial soils of the Upper Nile, one of the numerous species included under this name, often attains a height of from 15 to 20 feet, and is very pro-

ductive. It is nearly equal in nutritive value to the average of our English wheats, and yields a beautiful white flour. According to recent analyses, buckwheat, deprived of its husk, contains 15, and *dari* meal 8 to 9 per cent of gluten.

10°. The BEAN, the PEA, the LUPIN, the VETCH, the LENTIL, and other varieties of pulse, contain, as a distinguishing character of the whole class, a large percentage of gluten, mixed with a comparatively small percentage of fat. On an average, the proportion of gluten is about 24, and of fat about 2 in every 100. The gluten of these kinds of grain resembles that of the oat, and does not, therefore, fit bean or pease meal for being converted into a spongy bread. The large proportion in which this ingredient is present in them, however, renders all kinds of pulse very nutritious. Eaten alone, however, they have a constipating or costive quality; but a proper admixture of them with other kinds of food, especially with such as contain a larger proportion of oil or fat, is found to give both strength and endurance to animals which are subjected to hard labour. It is in this way that a certain quantity of beans given to horses among their oats, is found so serviceable in this country.

It is because also of the same large percentage of gluten that the chick-pea, one of the seeds known as *gram* in the East, is considered, when roasted, to be more capable of sustaining life, weight for weight, than any other kind of food. For this reason it is selected by travellers about to cross the deserts, where heavy and bulky food would be inconvenient.

Of all these varieties of grain a kind of bread is made by those who live upon them, and they are all more or less used in this form for human food. Only two of them, however, I believe—wheat and rye—possess the property, when mixed with yeast or leaven, of forming a light spongy bread, which can be kept for a time without becoming unpalatable. And of the two varieties of bread yielded by these grains, that made from wheat is the more dry and crummy, the more fair to look upon, and the more agreeable to the taste. Hence the universal preference which exists for the flour of wheat and for wheaten bread wherever they can easily be obtained.

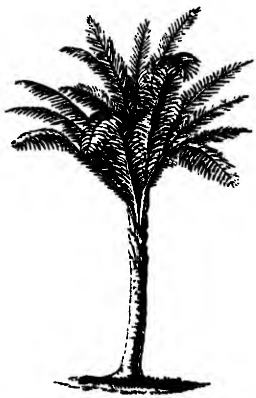
The cereals raised in the United States may be cited as an illustration of the enormously increased production of breadstuffs during the thirty years, 1840 to 1870 :—

Cereals.	Millions of bushels in 1840.	1850.	1860.	1870.
Indian corn,	377	592	838	760
Oats,	123	146	172	282
Wheat,	85	100	173	288
Barley,	4	5	16	30
Rye,	19	14	21	17
Total,	608	857	1220	1377

But trees also share with corn-bread to a considerable extent in the nutrition of the human race. Among these the sago-palm, the Chilian pine, the banana or plantain, and the date, the fig, and the bread-fruit tree, are deserving of especial notice.

11°. The SAGO-PALM (*Sagus rumphii*) is cultivated in many places, but it is the chief support of the inhabitants of north-western New Guinea, and of parts of the coast of Africa. The meal is extracted from the pith by rubbing it to powder, and then washing it with water upon a sieve. It is baked by the natives into a kind of bread or hard cake, by putting it for a few minutes into a hot mould. The exact nutritive value of this meal has not been chemically ascertained. It has been stated, however, that 2½ lb. of it are sufficient to serve for a day's sustenance to a healthy full-grown man. And as each tree, when cut down in its seventh year, yields 700 lb. of sago-meal, it has been calculated that a single acre of land planted with 300 trees—one-seventh to be cut down every year—would maintain 33 men.

Fig. 14.



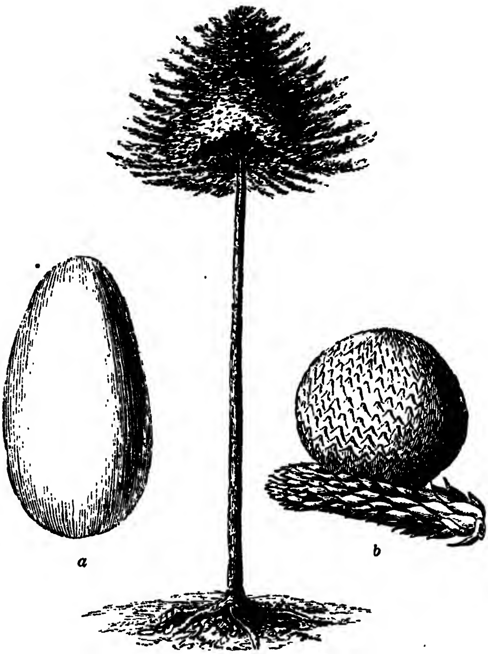
Sagus rumphii—The Sago-palm. Scale, 1 inch to 20 feet.

Other so-called sago-palms are known. One of these, *Cycas pectinata*, has a stem 10 feet high crowned with beautiful foliage, and grows on the flats of the Great Runjeet River in Sikkim, &c.

12°. But the CHILIAN PINE (*Araucaria imbricata*), now known among us for its beauty, is still more conspicuous as

a feeder of men. In our British woods the tiny squirrel supports its life during the winter months on the seeds of the larch, the pine, and the Scotch fir, which we plant for orna-

Fig. 15.



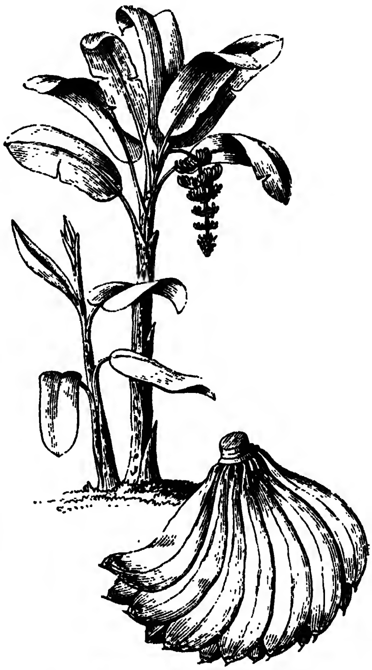
Araucaria imbricata—The Chili Pine.
Scale, 1 inch to 40 feet.
a Kernel of seed, the natural size; *b* Cone, 1 inch to 10 inches.

ment or use. But on the western slopes of the Andes of Chili and Patagonia, the lofty araucaria extends in natural forests, bearing huge cones six inches and more in diameter. The seeds contained in these are large, 200 or 300 in number, and twice the size of an almond, and supply the natives with a great part of their usual food. "The fruit of one large tree will maintain eighteen persons for a year;" and this year by year, without the necessity of cutting down and replanting, as in the case of the sago-palm.

We do not know the composition of these pine-seeds, but they probably do not differ much from the beechnut, the chestnut, and the acorn, all of which are rich in gluten.

13°. THE BANANA OR PLANTAIN TREE.—Of some fruits, tales nearly as wonderful are told. The beautiful banana, for example, the ornament of country-houses in tropical countries, is said to yield from the same extent of ground a larger supply of human food than any other known vegetable. It is distinguished by a large waving fanlike leaf and pendent branches of golden fruit. The fruit of a single tree sometimes weighs 70 or 80 lb., but averages from 30 to 40 lb.; and, according to Humboldt, the same space of 1000 square feet, which will yield only 462 lb. of potatoes, or 38 lb. of wheat, will produce 4000 lb. of bananas, and in a shorter period of time!

Fig. 16.



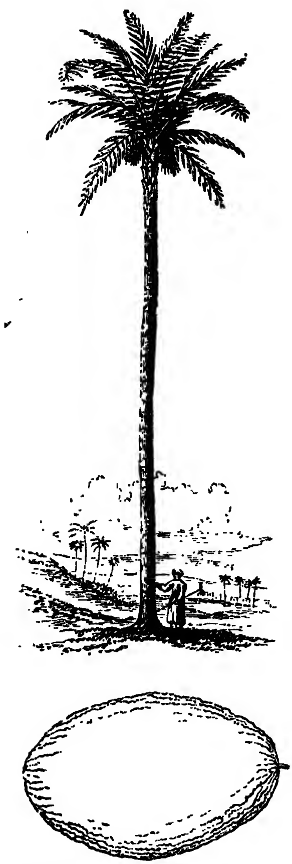
Musa sapientum—The Banana Tree.
Scale, 1 inch to 10 feet.
Fruit, 1 inch to 5 inches.

The fruit, however, contains when ripe 74 per cent of water. Of the 26 remaining parts 20 are sugar, and 2 gluten or flesh-forming substances. Thus, like rice, it is not by itself a perfect food, requiring the addition of some more nitrogenous material, as pulse or lean meat. Even when dried and converted into meal, it is less nutritious than the meal of any of the varieties of grain above mentioned. In tropical countries it is nevertheless a most valuable food, and is so extensively consumed as to take the place of our cereal grains as the common article of diet. About 6½ lb. of the fruit, or 2 lb. of

the dry meal, with ¼ lb. of salt meat or fish, form, in tropical America, the daily allowance for a labourer.

The unripe fruit is sometimes used; it is dried in the oven, and in this state is eaten in the manner of bread. When thus dried, it may be kept for a long time without spoiling, and is usually carried with them in this dry state by the natives when they are proceeding on a long journey.

Fig. 17.



Phœnix dactylifera—The Date-palm.
Scale, 1 inch to 20 feet.
Fruit, 1 inch to 2 inches.

The chemical reason why the unripe fruit is chosen for this purpose is, that while unripe, the fruit is filled with starch, so that when dried it has a resemblance to bread both in taste and composition. As the fruit ripens, this starch changes into sugar, and the fruit becomes sweet. In this state, though more pleasant to eat when newly pulled, it is less fit either for drying or for preserving.

14°. The Date.—Many other fruits are more nutritious, weight for weight, than the banana, though none may probably be compared with it as an abundant producer of food. The date, for example, "the bread of the desert," is much less watery, and though somewhat deficient in flesh-formers, is capable of supporting life, and of sustaining unaided the strength of man, for an indefinite period.

The date-palm (*Phœnix dactylifera*), the tree which yields this fruit, is invaluable amid parched sands and arid deserts. Wherever a spring of water appears amid the sandy deserts of Africa (between 19° and 35° N.

latitude), this graceful palm yields at once both its grateful shelter and its nourishing fruit. The date-palm comes into full bearing in thirty years: then for seventy years it annually produces 15 to 20 bunches of fruit, each bunch weighing 15 to 20 lb. Where all other crops fail from drought, the date-tree still flourishes. In Egypt and Arabia it forms a large portion of the general food, and among the oases of Fezzan "nineteen-twentieths of the population live upon it for nine months of the year." It is dried and pounded, and forms a sort of cake.

15°. THE FIG.—The fig, like the date, is a native of warm climates. Of the chemical history of this and some other fruits we know more than we do as yet of the date. In the perfectly dry state it is about as nutritious as rice. In the moist state, as it is imported, it will go considerably further in feeding, and especially in fattening or adding generally to the weight of an animal, than an equal weight of wheaten bread!

Thus figs as imported, and wheaten bread in its usual state, consist respectively of—

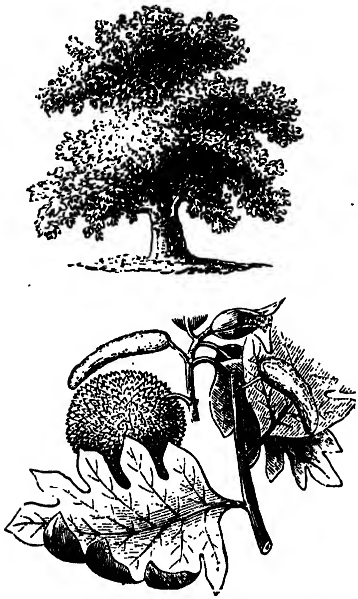
	Figs.	Wheaten Bread.
Water,	18½	40
Gluten,	6	7
Starch, sugar, gum, &c.,	66	51
Mineral matter,	2½	1½
Fibre,	7	½
	100	100

The fig, it will be seen by comparing the above columns, contains nearly as much gluten as wheaten bread, while in starch and sugar it is sixteen per cent richer. The perfectly dry gooseberry is about as nutritive as ordinary wheaten flour.

16°. THE BREAD-FRUIT TREE (*Artocarpus incisa* and *A. integrifolia*) is remarkable for its large and brilliant leaf, and for the general beauty of its appearance, in which respect none of our forest-trees can compare with it. But it is most remarkable for the abundant, peculiar, and nutritious fruit it yields. This fruit is nearly round, and attains to a considerable size. It grows abundantly, and covers the tree for eight or nine months without interruption, and the crops ripen in succession. There are various ways of cooking it, for it is

seldom relished raw. While the fruit is on the tree, it is plucked before it is perfectly ripe, while the rind is still green, but the pith snow-white, and of a porous and mealy texture. It is then peeled, wrapped in leaves, and baked on hot stones. In this state it tastes like wheaten bread, sometimes rather sweeter. When quite ripe, the starch, as in the banana, has become partly changed into sugar, so that the pith is pulpy, and of a yellow colour, and can be eaten uncooked, but it has still a disagreeable flavour. To serve for food during the three months when the tree ceases to bear, the unripe fruits, after being peeled, are laid in a paved pit and covered with leaves and stones; they there ferment and become sour, and form a kind of paste, which tastes like black Westphalian bread when not thoroughly baked. The quantity required for daily use is taken from the pit, made into lumps about the size of the fist, rolled in leaves, and baked on stones as before. These lumps of bread keep for weeks, and are a very good provision in journeys.

Fig. 18.



Artocarpus incisa.—The Bread-fruit Tree. Scale, 1 inch to 40 feet. Leaf and fruit, 1 inch to a foot and a half.

The crops of this fruit are so abundant that three trees are said to be sufficient to maintain a man for eight months. If so, it is more productive even than the banana or the sago tree. "Whoever," says Captain Cook, "has planted ten bread-fruit trees, has fulfilled his duty to his own and succeeding generations as completely and amply as an inhabitant of our rude clime who, throughout his whole life, has ploughed during the rigour of winter, reaped in the heat of summer, and not

only provided his present household with bread, but painfully saved some money for his children."

On the islands of the Indian Archipelago, and on the island groups of the South Sea, this tree is found. The fruit is best, however, on the Friendly and Marquesas Islands. It has never been observed wild, but the whole species has passed into a cultivated state, and it is therefore probable, says Meyen, "that man settled wherever he found a bread-fruit tree. Even yet, the favourite situation of the fragile Indian huts is under its shady branches."[1]

While unripe, it contains much starch, which during the ripening is partly changed into sugar; but how much gluten, fat, cellulose, and water are present in it does not appear to have been ascertained. The *jak* fruit is the produce of *Artocarpus integrifolia.*

The quantity of water they contain is a character of fruits which is very important. By this they are distinguished in a remarkable manner from the different varieties of grain. Thus the fruits of

Bananas or plantains contain	.	74 per cent of water.		
Plums, and other fleshy fruits,	.	77	,,	,,
Apples, gooseberries, &c.,	. .	83	,,	,,

The consequence of this composition is, that in fruits all the nutritive matter is diluted with a large quantity of water, and in this state experience has shown that all nutritive substances are more grateful to the healthy stomach, and more easily digested. It is for this reason that, in preparing our dry grains for food, we almost invariably imitate this preparatory process of nature. Even in baking our bread, as we have seen above, the result of our operations is that we convert it into a light and spongy mass containing nearly half its weight of water. And yet we talk of this as *dry* bread, and rarely eat it without some accompanying fluid.

The ROOTS and TUBERS we use as food are naturally still more watery than fruits. The potato, the carrot, and the turnip, for example, contain respectively in 100 lb.—

	Water.	Dry food.
The potato, ...	75	25
The carrot, ...	88	12
The turnip, ...	92	8

[1] Meyen's Geography of Plants (Ray Society), p. 321.

The gourd tribe are still more remarkable for the quantity of water they contain. The water-melon, for example, contains 94 per cent, the vegetable marrow 95 per cent, and the cucumber 97 per cent of water! No wonder that Jonah's gourd could spring up in a night—that this tribe of plants should be so much esteemed in hot climates where thirst rages—or that old Mehemet Ali should have been able to eat up an entire 40-lb. melon after the substantials of his dinner were disposed of!

The food of the Sandwich Islanders largely consists of a preparation called *poi*, made from the tuber of a semi-aquatic plant, the *Colocasia esculenta*, called in the native language *kalo*. The root or tuber is baked in heated stones, pounded into a paste, mixed with water, and allowed to ferment. After standing for a few days, the sour mixture is ready for use. A patch of kalo 40 feet square will supply food for one man for a year. One square mile would support 15,000 inhabitants. But the land must be flooded a few inches, and carefully cultivated. The same plant (*Colocasia esculenta*) is also largely grown in Egypt, where it is known as *koulkass*. *Colocasia macrorhiza* is extensively grown in the South Sea Islands.

17°. The Turnip and Carrot.—The dry substance of the roots and green vegetables we use as food resembles that of seeds and fruits in general composition. The dried meal of the parsnip, for example, contains gluten associated with starch and sugar, and is very nutritious. That of the turnip is quite equal in this respect to Indian-corn meal, being only deficient in fat. Hence a little oily food should be always used along with a turnip diet. Attempts have been made to manufacture a palatable meal from dried turnips, but the disagreeable taste of the root so clings to the meal as hitherto to have rendered it unsuited for human consumption.

18°. The Potato is more important as a variety of human food than any other root we cultivate, and is remarkable for being grown over a greater range of latitude than any other cultivated plant. The dry substance which it contains—the potato-meal, that is—is unsuited for being made into bread alone, though it is used to some extent as an admixture with wheaten flour, and is said in most cases to improve the bread in lightness and general appearance. The dried potato is less

nutritive, weight for weight, in the sense of supporting the strength, and enabling a man to undergo fatigue, than any other extensively used vegetable food of which the composition is known, not even excepting rice or the plantain. It approaches nearest, indeed, to the plantain, though it is somewhat inferior to that fruit. Thus, the *dry* substance of these three forms of food contains—

	Rice.	Potato.	Banana or plantain.
Gluten, ...	9	5	7
Starch, sugar, &c., . . .	89	81	85
Fat, ...	½	1	3
Salts, ...	½	4	1

There is, therefore, some similarity among these three kinds of food, in so far as they all differ from our cereal and other grains and roots, in containing a smaller proportion of the ingredient represented by the gluten of wheat. And in the use of them all, it is remarkable that a chemical or physiological likeness is indicated by the observation that the tribes of people who live exclusively or even chiefly on any of these three vegetable productions, are distinguished by the size and prominence of their stomachs! The Hindoo who lives chiefly on rice, the negro who lives on the plantain, the Russian soldier who consumes much sour soup, and the Irishman who lives exclusively on the potato, are all described as being more or less pot-bellied. This peculiarity is to be ascribed in part, I suppose, to the necessity of eating a large bulk of food, in order to be able to extract from it a sufficient amount of necessary flesh-forming or nitrogenous sustenance. And that this deformity is somewhat less conspicuous in the Irish potato-eater than in the plantain-loving negro, or even the rice-devouring Chinaman and Hindoo, is probably to be ascribed to the somewhat larger proportion of the ingredient gluten which is present in the more mixed diet of the potato-eater.

One remarkable circumstance in which the three kinds of meal just spoken of differ from each other, is in the size of the grains of starch in each. As seen in the following figures—all drawn to the same scale—the starch-granules in the potato are very large, having sometimes a length of two or three thousandths of an inch. Those of the plantain, though considerably larger than the granules of wheat or rye (p. 70),

average less than half the size of those of the potato; while those of rice are angular, and have an average diameter of less than one five-thousandth of an inch.

Fig. 19.

Granules of Potato-starch. Granules of Plantain-starch. Granules of Rice-starch.

19°. The Onion is worthy of notice as an extensive article of consumption in this country. It is largely cultivated at home, and is imported, to the extent of seven or eight hundred tons a-year, from Spain and Portugal. But it rises in importance when we consider that in these latter countries it forms one of the common and universal supports of life. It is interesting, therefore, to know that in addition to the peculiar flavour which first recommends it, the dry substance of the onion is remarkably rich in flesh-formers. According to my analyses, the dried onion-root contains from twenty-five to thirty per cent of gluten. It ranks in this respect with the nutritious pea and the *gram* of the East. It is not merely as a relish, therefore, that the wayfaring Spaniard eats his onion with his humble crust of bread, as he sits by the refreshing spring: it is because experience has long proved that, like the cheese of the English labourer, it helps to sustain his strength also, and adds—beyond what its bulk would suggest—to the amount of nourishment which his simple meal supplies. It has been used as a nutritive and medicinal food for fowls.

20°. Among roots which are important articles of diet in more limited districts, may also be mentioned the tuber of a lily (*Lilium pomponium*) which is roasted and eaten in Kamtchatka, and is there cultivated as we rear the potato. The

sweet potato, a plant belonging to the Convolvulus Order, must not be forgotten: it is as rich as the common potato. It is grown chiefly in the warmer parts of the American continent. The yam, another tuber of tropical and sub-tropical countries, is not so rich as the sweet potato, but forms an important article of food in the East and West Indies, the South Sea Islands, and Japan. In the following table of percentage composition will be found much information as to the roots commonly used for food, with a column giving the proportions of the two chief nutrients in each root. Let it be remembered that such proportion in a perfect food is about 1 : 6.

	Water.	Flesh-formers.	Starch, &c.	Fat.	Ash.	Ratio of flesh-formers to heat-givers.
Potato, ...	75.0	1.2	18.0	0.3	1.0	1 : 16
Carrot, ...	89.0	0.5	5.0	0.2	1.0	1 : 10
Parsnip, ...	81.0	1.2	8.7	1.5	1.0	1 : 10
Turnip, ...	92.8	0.5	4.0	0.1	0.8	1 : 8
Onion, ...	91.0	1.5	4.8	0.2	0.5	1 : 3½
Sweet potato, . .	74.0	1.5	20.2	0.1	1.5	1 : 13
Yam, ...	79.6	2.2	16.3	0.8	1.5	1 : 7½
Beetroot, ...	82.2	0.4	13.4	0.1	0.9	1 : 30
Jerusalem artichoke,	80.0	2.0	14.4	0.5	1.1	1 : 7

LEAVES.—From roots we turn to leaves, which form no inconsiderable proportion of the daily sustenance of European nations. The greater number of animals, wild as well as domestic, live upon the leaves of plants. Our oxen feed upon the grasses; and even the huge elephant and the sloth find their nourishment on the leaves of the forests in which they live. Among those which are raised for human food, the cabbage is a regular field-crop; and many others are cultivated less extensively in our gardens.

Leaves are generally rich in gluten; many of them, however, contain other substances in smaller quantity, associated with the gluten, which are unpleasant to the taste, or act injuriously upon the general health, or are fibrous and indigestible, and which therefore render them unfit for human food. Dried tea-leaves, for example, contain about twenty-five per cent of gluten; and therefore, if they could be eaten with relish, and digested readily, they might furnish as much flesh as beans or peas.

21°. The Cabbage, the Cauliflower, and Broccoli, though containing ninety per cent of water, are, so far as concerns their dry matter, rich in flesh-formers or gluten. The unripe pods of the scarlet runner and French bean are still more nitrogenous. In Thibet and Nepaul the paper mulberry, *Broussonetia papyrifera*, is used for feeding cattle in the winter months. The young leafy shoots are cut, dried, and stacked as fodder. When eaten frequently, however, and in large quantity, any vegetable foods rich in gluten or flesh-formers, have a costive or binding tendency; hence the propriety of eating them with fat and oily food. Bacon and greens, like pork and pease-pudding, is a conjunction of viands which does not owe its popularity either to old habit or to the mere taste of the epicure. It is in reality an admixture which constitutional experience has prescribed as better fitted to the after comfort of the alimentary canal of every healthy individual, than either kind of food eaten alone.

And so with a dish common in Ireland under the name of Kol-cannon. The potato, as we have seen, is poor in gluten—the cabbage is unusually rich in this ingredient; mix the two, and you approach the composition of wheaten bread. Beat the potatoes and boiled cabbage together, put in a little pork-fat, salt, and pepper, and you have a kol-cannon which has all the good qualities of the best Scotch oatmeal, and to many would be more savoury and palatable. Take a pot-bellied potato-eater, and feed him on this dish, and he will become not only stronger and more active, but he will cease to carry before him an advertisement of the kind of food he lives upon, and his stomach will fall to the dimensions of the same organ in other men. In Provence small farmers dine from a *pot-au-feu* containing only potatoes and cabbages, beaten together, without milk or butter.

Such are the principal varieties of vegetable food which—partly in the form of baked bread, and partly cooked in other ways—are, at the present day, most largely employed in the feeding of the human race. We have seen in all of them—

First, That they contain a sensible proportion of four important constituents—gluten, starch, fat, and mineral matter.

Secondly, That when the proportion of any of these is too small, chemistry indicates, and experience suggests, that an additional quantity of this deficient substance should be added

in the process of cooking, or preparatory to eating. Thus we consume butter with our bread, and mix it with our pastry, because wheaten flour is deficient in natural fat; or we eat cheese or onions with the bread, to add to the proportion of gluten it naturally contains. Salt, oil, and milk kneaded with the finest flour made the celebrated bread of Cappadocia, greatly relished by wealthy Romans. Imitations of this are seen in milk-bread and Scotch shortbread. So we eat something more nutritive along with our rice or potatoes—we add fat to our cabbage—we enrich our salad with vegetable oil—eat our cauliflowers with melted butter—and beat up potatoes and cabbage together into a nutritious kol-cannon.

Thirdly, That in all natural varieties of vegetable food which are generally suitable for eating without cooking, a large percentage of water is present. In preparing food in our kitchens we imitate this natural condition. Even in converting our wheaten flour into bread, we, as one important result aimed at, mix or unite it with a large proportion of water.

All the kinds of food by which the lives of masses of men are sustained being thus constituted, it is obvious that those vegetable substances which consist of one only of the constituents of wheaten bread, cannot be expected to prove permanently nutritious; and experience has proved this to be the case. The oils or fats alone do not sustain life, neither does starch or sugar alone. With both of these classes of substances, as we have seen, a certain proportion of gluten is associated in all our grains, fruits, and nutritive roots. And there must likewise be a small though distinct quantity of mineral matter present. Some of this we add, as common salt, but most vegetables contain the phosphates and potash salts which are necessary for the formation of bone and the renewal of the saline matter in the blood.

Hence arrowroot, which is only a variety of starch, cannot give strength without an admixture of gluten in some form or other. To condemn a prisoner to be fed on arrowroot or the maize-starch sold as corn-flour, alone, would be to put him to certain death by a lingering, torturing starvation. The same is true, to a less extent, of tapioca, and of most varieties of sago, all of which consist of starch, from which nearly all the gluten has become removed. Even gluten, when given alone

to dogs, has not kept them alive beyond a few weeks; so that no vegetable production, it may be said, and no kind of artificially prepared food, in which starch, sugar, or some similar substance, and gluten at least are not united, will support life. If they contain at the same time a certain proportion of fat, they will admit of more easy digestion, and of a more ready application in the stomach to the purposes of nutrition; and if they are either naturally permeated with a large quantity of water, or are transfused with it by artificial means, they will undergo a more complete and easy dissolution in the alimentary canal, and will produce the greatest possible effect in ministering to the wants of animal life.

It is interesting to observe how very generally adjustments of this kind have been made to the wants of animals, in the natural composition of the eatable parts of plants. But it is still more interesting to observe how experience alone has almost everywhere led men to a rude adjustment, in kind and quantity, of the forms of nutritive matter which are essential to the supply of their animal wants under the circumstances in which they are placed. Climate as well as the temperament of a race has much to do with the adjustment of foods and dietaries. A vegetable diet does not suit John Bull. That gentleman would be much troubled with dyspepsia, and have to take enormous quantities of quack pills to keep him in good humour. In Spain it produces no mischief; but even the Dons find it desirable to mix their oil, bread, onions, and lettuce in proportions which the dictates of taste and the exigencies of the system have settled. And the absolute necessity for such adjustment is proved by all physiological history. For when, through force of circumstances, or through distorted taste, the natural instinct for such adjustment cannot be gratified, or is foolishly thwarted, the health is endangered, the constitution gradually altered, the temperament modified, life shortened, families extinguished, and whole races of men swept from the face of the earth. Such, looked at in their final effects, are the influences of the kind of food in which individuals indulge, or by which nations are supported.

I have omitted to describe for lack of space many other vegetable foods used by man. *Bromicolla aleutica*, a sea-weed, is eaten by the natives of the Aleutian Isles whenever their supply of fish fails. It forms a layer two feet thick at Unimah,

where it is covered with a grassy growth. Iceland moss, really a lichen, is gathered by the peasants of Iceland, boiled with water, and then added to milk: sometimes it is dried, ground to powder, and made into cakes and baked. The lives also of arctic travellers have been supported on lichens; while numerous kinds of fungi or mushrooms are not only edible but nutritious.

CHAPTER VI.

THE BEEF WE COOK.

The fibrin or myosin and water of beef—Composition of beef compared with that of wheaten bread and wheaten flour.—Striking differences.—Dried flesh compared with dried oat-cake.—More fat in domesticated animals and such as are fed for the butcher.—Composition of fish.—Richness of the salmon and the eel.—Less fat in fowls.—Eating butter with fish.—Composition of the egg.—Albumen or white; its properties and relations to gluten and fibrin. —Oil in the yolk, and in the dried egg.—Composition of milk.—Milk allied both to animal and vegetable forms of food.—Milk a model food.—Importance of a mixed food, containing much liquid.—Adjustment of the several ingredients of food in cooking.—Qualities of different kinds of cheese. —Composition of new and skimmed milk cheeses.—Comparison with milk. —Cheese as a digester.—Solvent power of decayed cheese.—Customary practices in cooking.—Comparative value of different kinds of animal food.—Loss of beef and mutton in cooking.—Effects of heat upon meat.—Constituents of the juice of meat.—Kreatine.—Effects of salt upon meat.—Loss of nutritive value in salting.—How to boil meat and make meat-soup. —Animal fats; their analogy to vegetable fats.—The solid fat of beef, mutton, and palm-oil.—Composition of human fat, goose-fat, butter, and the oil of the egg.—The liquid part of animal fats.—Identity of animal and vegetable food as regards the mineral matters they respectively contain.

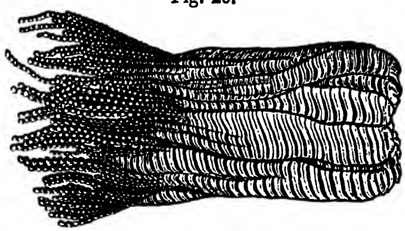
Beef and bread are the staples of English life; and as the study of wheaten bread in the preceding chapter gave us the key to the composition and nutritive qualities of all other vegetable substances, so an examination of beef will help us to a clear knowledge of all other kinds of animal food.

1°. Flesh.—If a piece of lean fresh beef be dried in the hot sunshine, or in a basin over boiling water, it will shrink, dry up, diminish in bulk, and lose so much water, that four pounds of fresh, newly-cut beef, will leave only one pound of dried flesh.

Again, if we take a piece of lean beef and wash it in separate portions of clean water, its colour will gradually disappear. The blood it contains will be washed out, and a white mass of muscular or fibrous tissue with a little fat and a few membranes will remain. If this be put into a bottle with alcohol or ether, a variable proportion of fat will be dissolved out of it, and the whole fibrous mass will now be drier and more compact than before. Through this fibrous mass many minute vessels are scattered, but it chiefly consists of a substance to which chemists, from its fibrous appearance, until recently, gave the name of *fibrin*, believing it to be identical with the fibrin of the blood. It is now called *myosin*.

The annexed woodcut (fig. 20) shows the structure of muscle, as seen under the microscope. The cross wrinkles represent the way in which the fibres contract in the living animal.

Fig. 20.



The fibres of lean muscle, showing how they are disposed or arranged, the particles of which they are composed, and how they shrink or contract.

Of this myosin the lean part of the muscles of all animals chiefly consists; it is therefore the principal constituent of animal flesh. It resembles the gluten of plants very closely in composition and properties—insomuch that, in a general comparison of animal with vegetable food, we may consider them for the present as absolutely identical.

Thus we have separated our beef—besides the small quantity of blood and other matters washed out of it by the water—into three substances, water, myosin, and fat. Its composition, as compared with that of wheaten bread and wheaten flour, is represented as follows:—

	Lean beef.	Wheaten bread.	Wheaten flour.
Water (and blood), . .	77	40	15
Myosin or gluten, . .	19	7	10
Fat, ...	3	1	1
Starch, &c., ...	...	50	73
Salt and other mineral matters,	1	2	1
	100	100	100

Lean beef, therefore, agrees with wheaten flour and bread, in containing water and fat—only in beef the water is as great as it is in the potato or the plantain. It agrees with them also in containing a substance, myosin, which represents in the animal the gluten of the plant. The main differences between beef and bread are, *first*, that the flesh does not contain a particle of starch, which is so large an ingredient in plants; and, *secondly*, that the proportion of myosin in ordinary flesh is about three times as great as that of gluten is in ordinary wheaten bread. Or a pound of beefsteak is as nutritive as three pounds of wheaten bread, in so far as the nutritive value of food depends upon this one ingredient, which is, however, only an approximative gauge. In the dry matter of lean flesh, also, the proportion of myosin is greater than that of gluten in any known vegetable food, and very much greater than in dried bread made from any of our cultivated grains.

This latter fact will become more apparent if we compare perfectly dry lean flesh with perfectly dry oat-cake—oatmeal being the richest of our common kinds of meal, both in gluten or nitrogenous matter, and in fat.

	Dried flesh.	Dried oat-cake.
Myosin, gluten, &c.,	85	18
Fat,	10	10
Starch,	0	66
Salts,	5	2
Fibre,	0	4
	100	100

Here we have the main differences between the lean flesh of animals and the most nutritive of our grains presented in a very striking light. The animal food contains nearly five times as much of what for the moment we may call gluten; but it is wholly deficient in the other main ingredient of vegetables—the starch—which in the dried oatmeal forms nearly seven-tenths of the whole weight.

The flesh of wild animals is represented very nearly by the lean beef of which the composition is given above. Wild animals generally contain little fat. But it is not so with our domesticated animals, and especially such as are reared for food. They all contain much fat, either collected by itself in various parts of the body (the suet or tallow), or

intermingled with the muscular fibre, as in the highly-prized marbled beef in which the English epicure delights. In the boiling-houses at Port Phillip, a small merino sheep of 55 lb. weight gives 20 lb. of tallow, which is nearly two-fifths of the whole. In heavier sheep the proportion of fat increases, four-fifths of all the weight above 55 lb. being tallow. In beef and mutton, such as is met with in our markets, from a third to a fourth of the whole dead weight generally consists of fat. And Lawes and Gilbert have shown by numerous experiments in fattening oxen, sheep, and pigs, that two-thirds of the *dry* increase in weight of these animals is fat. About one-fourth of the dry substance of ordinary meat may be set down as fat, which to a certain extent represents and replaces the starch of vegetable food. Indeed, travellers living upon dry wild game have found it necessary to kill sheep for the sake of their fat only, or to introduce oil, sugar, or starchy matter. But a simple diet of flesh is often practicable. A South African sheep of about 200 lb. weight served one of Mr Galton's people—he taking two meals a-day—ten days, or ten men one day, without bread or vegetables. An average ox was equal to seven sheep, and a giraffe to two oxen.

Fowls contain less fat than butcher-meat; though, when crammed and fed upon food rich in fat, the capon and the ortolan, and the diseased livers of the goose, become as rich as the fattest beef or mutton.

The composition of other kinds of flesh which we eat as food is much the same as that of beef. Veal and venison contain less fat, while pork contains more. Each variety also possesses a peculiar flavour and a faint odour, which is characteristic of the species, and sometimes of the variety of the animal. In some cases, as with our mountain mutton, this peculiar flavour is a high recommendation; in others, as with the sheep of the Low Countries, and with the goat, it renders them to many altogether unpalatable.

2°. Fish varies a good deal in the amount of fat present in association with the myosin, albumen, and fibrin. Whiting, soles, and pike are less rich in fat than salmon, mackerel, and eels. But the proportions in the same kind of fish are liable to variation—the herring especially being very much fatter at some seasons and on some coasts than on others. But

salmon is justly considered a *rich* fish, since it commonly contains three times as much fat as the haddock. The epicure has also a substantial reason for his attachment to the eel, since it contains a considerably greater weight of fat than it does of muscular fibre. Schutz has made a comparative analysis of lean muscle or pure flesh of oxen and of carp, and the results are as follows:—

	Beef.	Carp.
Fibrin or myosin, &c.,	15.0	12.0
Albumen,	4.3	5.2
Extract, soluble in alcohol, and salts,	1.3	1.0
Extract, soluble in water, and salts,	1.8	1.7
Phosphates,	traces.	traces.
Fat,	0.1	,,
Water,	77.5	80.1
	100.0	100.0

It appears, therefore—

First, That the dried flesh of all the animals which we most usually consume for food consists essentially of the nitrogenous matters known as myosin, fibrin, and albumen.

Secondly, That the proportion of fat is variable, and that those varieties of animal food are usually most esteemed for human food in which a considerable proportion of fat is present. Hence,

Thirdly, Where the proportion of fat is naturally small, we endeavour to increase it by art; as in feeding the capon. Or we eat along with those varieties in which it is small some other food richer in fat. Thus we eat bacon with veal, with liver, and with fowl; or we capon the latter, and thus increase its natural fat. We use melted butter with our white fish, or we fry them with fat; while the herring, the salmon, and the eel, are usually both dressed and eaten in their own oil. If the reader will take the trouble of consulting any popular cookery-book, he will find that sausage, and other rich mixed meats, are made in general with one part of fat and two of lean—the proportion in which they exist in a piece of good marbled beef,—art thus unconsciously again imitating nature.

3°. THE EGG.—Akin to flesh and fish is another form of animal food—the egg. The egg of the domestic hen is that which is most commonly known, and most extensively used

as food. It consists of three principal parts—the shell, the white, and the yolk. The shell is mainly composed of carbonate of lime or hard chalk, and is intended chiefly as a protection to the inner part. It is penetrated, however, by numerous minute holes or pores, through which the air is capable of passing, and by means of which it is conveyed to the young bird during the process of hatching.[1] It forms rather more than a tenth part of the weight of the egg, the white forms sixth-tenths, and the yolk three-tenths. A common-sized hen's egg weighs about 900 grains, and consists of about—

White, ...	530 grains.
Yolk, ...	270 ,,
Shell and membranes, ...	100 ,,
	900

The white of the egg is so called, because, when heated, it coagulates into a white solid substance, which is insoluble in water, and almost free from taste. It contains a substance of nitrogenous and flesh-forming character called *albumen.* White of egg always contains a small proportion of fat, and 1 per cent of phosphate of lime. Though different in appearance and in sensible properties from myosin and gluten, it has a very close chemical relation to these substances, and serves the same purpose in the feeding of animals. We may, for the present, therefore, consider all the three—gluten, myosin, and albumen—as, in a nutritive sense, absolutely identical.

The yolk is of a yellow colour. It consists, in part, of a variety of albumen, and therefore, like the white, coagulates, though in a less degree, when the egg is heated. But if, after boiling, the dry hard yolk be crushed, and digested in ether, it becomes colourless, while the ether extracts and dissolves a bright yellow oil. This oil forms nearly two-thirds of the weight of the yolk, in its perfectly dry state. Thus the yolk, like flesh and fish, consists of fat intermixed with a substance which has a close resemblance to the gluten of plants.

1. Through these pores, also, the air enters, by the agency of which eggs, when kept, soon become rotten. If these pores are filled up by rubbing the new-laid egg over with fat, or in any similar way, it will keep fresh for a long time. It is then very nearly in the condition of the hermetically sealed meats now prepared for use on voyages or imported from Australia.

The egg contains, besides, a large percentage of water, amounting, as in fresh butcher-meat, to nearly three-fourths of its whole weight. Thus the egg, when deprived of its shell, consists, in the natural and in the dried states respectively, of—

Constituents.	In natural state.			Dried at 212° F.
	White.	Yolk.	Whole egg.	Whole egg.
Water, ...	85	$51\frac{1}{2}$	$71\frac{3}{4}$	...
Albumen, . . .	12	15	14	$49\frac{1}{2}$
Fat, &c., . . .	2	32	13	46
Phosphates, &c.,	1	$1\frac{1}{2}$	$1\frac{1}{4}$	$4\frac{1}{2}$
	100	100	100	100

The egg, therefore, as a whole, is richer in fat than fat beef. It is equalled, in this respect, among common kinds of food, only by pork and by eels. It is of interest to remark, however, that the white of the egg has but a trace of fat, and that albumen is a very constipating variety of animal food, so that it requires much fat to be eaten along with it, when consumed in any quantity, in order that this quality may be counteracted. It is, no doubt, because experience has long ago proved this in the stomachs of the people, that "eggs and bacon" have been a popular dish among Gentile nations from time immemorial. But eggs are in reality too rich in flesh-formers to be eaten alone, requiring the addition of fat or starch (as rice) to fit them for common use.

4°. Milk.—Another nutritious form of animal food is the well-known fluid milk. This, as we should expect, contains more water than beef or the egg; yet, contrary to what we might expect, not so much as the turnip, and much less than the melon.

Milk, by one well-known process, yields butter or fat, and by another, curd or cheese. The curd, to which chemists give the name of *casein*, from its forming cheese, resembles the gluten, myosin, and albumen, of which we have already spoken, and is classed along with them as a flesh-forming substance. It possesses also, weight for weight, about the same value, when used as food; and, like albumen, is distinguished, when eaten alone by adults, by a remarkably constipating property.

When the whey of milk, from which the curd and butter have been completely separated, is evaporated to dryness, a colourless sweet substance is obtained, which is known by the name of sugar of milk. When dried and burned in the air, milk also leaves behind a quantity of ash. These several ingredients exist in cow's milk, in the natural and in the dried states, in the following average proportions :—

	Natural state.	Evaporated to dryness.
Water, ...	87	...
Curd, chiefly casein, ...	4	31
Butter, or milk-fat, ...	$3\frac{1}{2}$	27
Sugar of milk, ...	$4\frac{3}{4}$	36
Ash, ...	$\frac{3}{4}$	6
	100	100

Thus milk appears to partake of the nature of both animal and vegetable food. It contains a large proportion of curd and butter, which represent the myosin and fat of beef, and, at the same time, a large proportion of sugar, which represents the starch of wheaten bread. The ratio of flesh-formers to heat-givers reckoned as starch is 1 to $3\frac{1}{2}$.

Human milk differs somewhat from the milk of the cow. Its average composition is as follows :—

Water, ...	$89\frac{1}{3}$
Curd or casein, ...	$1\frac{2}{3}$
Butter or milk-fat, ...	$2\frac{1}{4}$
Sugar of milk, ...	$6\frac{1}{3}$
Salts or ash, ...	$\frac{1}{4}$
	100

The principal differences are to be found in the proportions of saline matter, which in human milk is only one-third of that of cow's milk; and of curd, which is rather less than half. The milk of the mare and the ass closely resembles human milk; the milk of the goat, pig, and sheep, differs little from that of the cow.

Neither goat's milk nor cow's milk is so well adapted to the infant as human milk; and experienced mothers have learned to dilute and sweeten cow's milk when they have been forced to give it to their infants; thus the proper ratio of flesh-formers to heat-givers reckoned as starch, namely, 1 to 7, may be secured.

But human milk is far from yielding the same proportions of organic matter in every case. Strictly speaking, it is never the same in two individuals. It differs at different ages, in different constitutions, and in different states of health. The milk of women, from fifteen to twenty years of age, contains more solid constituents than that of women between thirty and forty. In two women of the same age, twenty-two, one a brunette and the other a blonde, L'Héritier found the milk of the former to be richer in solid nutrients than that of the latter by 5 parts in 100 of milk. While differences occur in different temperaments, other differences arise from disease.

As the natural food of the young mammalian animal of every species is the milk of its mother, that milk may be looked upon as a kind of model food for the species to which the animal belongs. Woman's milk, therefore, is the type of human food, and after its form and composition all other kinds of food should be adjusted, especially in the case of persons whose condition approaches to that of the child. Hence it seems reasonable to infer—

First, That our food ought to contain a due admixture of vegetable and animal substances, in which the proportions of the three most important constituents, (1) fat, (2) starch or sugar, and (3) fibrin, gluten, or some other nitrogenous or flesh-forming nutrient, are present in properly adjusted proportions.

Secondly, That the food, if not naturally liquid, should be intimately mixed with a large quantity of water before it is introduced into the stomach. This lesson we have already learned from the study of various natural forms of vegetable food.

The attainment of these two ends, in such a way as at the same time to please the eye and the palate, should guide, for the most part, the operations of the cook in his kitchen. They ought always to guide the operations of those who wish to prepare what it will be wholesome for the majority of men to eat.

5°. Condensed Milk.—Several methods of preserving and concentrating milk have been proposed and carried out. Of these the most successful consists in boiling down the milk after the addition of sugar. The condensed milk thus ob-

tained is met with in commerce as a thick opaque syrup preserved in closed tins, but capable of keeping good for some time after having been exposed to the air. It contains, in 100 parts, about—

Water,	26
Casein,	15
Milk-fat,	12
Milk-sugar,	18
Cane-sugar,	27
Mineral matter,	2
	100

6°. Cream, Skim-milk, Whey.—The cream which rises to the surface of milk consists mainly of the little globules of milk-fat previously suspended in the liquid, but these being specifically lighter than the liquid in which they float, ultimately rise towards the top. Cream contains about 40 per cent of milk-fat or butter, and 55 of water. Skim-milk contains much milk-sugar and casein or flesh-forming matter, while whey is little else but a solution of milk-sugar with one per cent of albumen.

7°. Butter.—As ordinarily met with in the market, good fresh butter contains 88 parts of milk-fat in 100, with 10 of moisture. Half a per cent of casein or curd, and a little milk-sugar and salt make up the remainder. Much salt and water are present in low-class butters, sometimes amounting to 33 per cent, or more; while other animal fats are largely used as adulterants or substitutes.

8°. Cheese.—The manufacture of cheese of different varieties, and the qualities which these varieties severally possess, are illustrations of the importance of a mixed food.

Cheese is eaten for two very different purposes; either as a part of the regular food, for the general sustenance of the body—or as a kind of condiment taken in small quantity along with or after the usual fare, as is common at dinner-tables.

In the making of cheese many different varieties are obtained, according as the proportion of cream is increased or diminished. When it is made from cream alone, what is called a *cream cheese* is obtained, which must be used when comparatively fresh, as it soon becomes rancid. When the cream of the previous night's milking is added to the new milk of the morning, a very rich cheese is made, like our English

Stilton; when good new milk only is employed, rich cheeses like the Cheddar are obtained; when an eighth or tenth of the cream is removed, highly esteemed cheeses, like the large-sized (120 lb.) Cheshires, are made, which will not hold together if all the cream be left in. There seems, at first sight, to be no connection between the application of bones to the Cheshire farmer's poor grass-land and the unexpected crumbling of the Cheshire dairymaid's cheese. Yet the connection is plain enough. The bones bring up richer grass; this gives richer milk; and this, treated in the old way, a fatter and therefore more crummy cheese. When the skimmed milk of the evening is added to the new milk of the morning, the mixed milk yields cheeses like the single Glo'ster. If the cream be once removed from the whole of the milk, it yields common skimmed-milk cheese; if it be twice creamed, it gives cheeses like some of the poorer sorts made in Friesland; and if skimmed for three or four days in succession, it yields the hard horny cheeses of Suffolk, locally known by the name of *Suffolk bank*,—a cheese which often requires an axe to cut it, and which is so hard "that pigs grunt at it, dogs bark at it, but neither of them dare bite it."

Now, in the making of cheese, the milk is first curdled—sometimes by the use of vinegar, but generally by means of rennet. The curd is then separated from the whey, in which the sugar of milk, and a small quantity of flesh-forming matter, remain dissolved; after this it is carefully pressed and dried. Were there no cream taken off the milk, therefore, the cheese as a food would differ from the milk chiefly in containing less water and little or no sugar. But when more or less of the cream is removed from the milk employed, the cheese becomes further removed from milk in its composition, and less fitted, therefore, to serve alone as a nutritious animal diet. The following numbers represent the composition of a rich Cheddar cheese when two years old, and of a common one-year-old skimmed-milk cheese made in Lanarkshire:—

	Cheddar.	Skim-milk.
Water,	36	44
Curd, or casein	29	45
Milk-fat,	30½	6
Salt and phosphates,	4½	5
	100	100

Both contain a very considerable proportion of water, and therefore in this respect they are not unsuited for immediate consumption as food. But while the fat in one amounts to nearly one-third of the whole weight, in the other it only reaches to six per cent.

But we shall have a clearer idea of the value of these varieties of cheese for a general diet, by comparing their composition in a dried state with those of milk, beef, and eggs, also in the dried state. This is seen in the following table :—

	Milk.	Cheese.		Beef.	Eggs.
		Cheddar.	Skim-milk.		
Casein (curd), . . .	31	45	80	85	49½
Fat (butter), . . .	27	48	11	10	46
Sugar, ...	36	...	...	...	...
Mineral matter, . .	6	7	9	5	4½
	100	100	100	100	100

We see from this table that both cheeses are free from sugar. Either of them, therefore, must be eaten with a quantity of vegetable food which may supply the starch or sugar required to make it equal to milk as a general nourishment. Again, the Cheddar cheese contains more fat even than the egg. It is too rich, therefore, to be used as an everyday diet by the generality of stomachs. It is partly for this, and partly for the previous reason, that "bread and cheese" are almost invariably eaten together.

Then, in the skim-milk cheese, we have only eleven of fat mixed with eighty of the very constipating curd. Experience has shown this to be far too little, and therefore butter or fat bacon, as well as bread, must be consumed along with these poorer cheeses, when much of them is intended to be eaten; or they must be cooked, in made dishes, along with some other variety of fat, or better, with some starchy food, as rice.

It is with a view to similar adjustments in the proportions of the several necessary ingredients of a nourishing food, that we mix eggs with sago, tapioca, and rice in our puddings, shred the oily yolk into our salad, boil rice with milk, and eat rich cheese with our macaroni. We also add bacon to liver, for the latter is poor in fat. Flour and soft curd of milk were kneaded together to make bread for the athletes of ancient Rome.

But cheese is often eaten also as a relish or condiment, only in small quantities at a time. It is chiefly the older and stronger-tasted varieties that are so used. They are generally very wholesome and digestible when taken in this way. As a *digester*, as some call it, cheese—that which is decayed and mouldy being preferred by connoisseurs—is often eaten after dinner. The action which experience seems to have proved it to possess, in aiding the digestion of what has previously been eaten, is both curious and interesting, and has had some light thrown upon it by chemical research.

When the curd of milk is exposed to the air in a moist state for a few days at a moderate temperature, it begins gradually to decay, to emit a disagreeable odour, and to ferment. When in this state, it possesses the property, in certain circumstances, of inducing a species of chemical change and fermentation in other moist substances with which it is mixed or is brought into contact. It acts after the same manner as sour leaven does when mixed with sweet dough.

Now, old and partially decayed cheese is said to act in a similar way when introduced into the stomach. It causes chemical changes gradually to commence among the particles of the food which has previously been eaten, and thus facilitates the dissolution which necessarily precedes digestion. Digestion, however, is only in part a species of fermentation; and the gastric juice, it is well known, *arrests* the process of putrefaction instead of facilitating it. Even if cheese, by some unexplained process, should assist digestion, it is only some kinds of cheese which will effect this purpose. Those are generally considered the best in which some kind of cheese-mould has established itself.[1] Hence the mere eating of a morsel of cheese after dinner does not necessarily promote digestion. If too new or of improper quality, it will only add to the quantity of food with which the stomach is probably already overloaded, and will have to await its turn for digestion by the ordinary processes.

We have seen that it is one of the special advantages possessed by the varieties of flour obtained from wheat and rye,

[1] It is an interesting circumstance that such kinds of cheese-mould, and the flavour and digestive quality which accompany them, may be propagated even in newer cheeses by inoculation—removing a bit of the new, that is from the interior, and putting in a bit of the old in its place.

that in the hands of the baker they form light and spongy bread. This is owing, as I have explained, to a peculiarly tenacious property which is possessed by the kinds of gluten contained in these two species of grain. But the same property is possessed to some extent by the white of the egg. It has a glairy consistence, which enables it, when mixed up with moistened flour, arrowroot, sago, &c., to retain the globules of air or of steam which are produced within it by fermentation or by heat. Thus, like the gluten of wheat, it enables the mixed materials to swell up into a porous mass. Hence the lightness which the white of egg gives to puddings, to cakes, and even to wheaten bread. In a less degree, a similar quality resides in the curd of milk, and hence one cause of the improvement in the appearance of bread which has been wholly or in part prepared with milk.

Before leaving this part of the subject, it may be useful to exhibit in a tabular form the composition, in 100 parts, of dried beef, eggs, and milk, compared with that of dried wheaten flour and dried oatmeal:—

	Beef.	Eggs.	Milk.	Fine wheat flour.	Oat-meal.
Fibrin, casein, albumen, or gluten, .	85	49½	31	12	17
Fat, ...	10	46	27	1	10
Starch or sugar, &c., . . .	...	...	36	86	71
Ash or mineral matter, . . .	5	4½	6	1	2
	100	100	100	100	100

From this table many interesting comparative deductions may be drawn.

9°. Cooking Flesh-meat.—In cooking animal food, plain boiling, roasting, and baking, are in most general favour in our islands. During these operations, fresh beef and mutton, when moderately fat, suffer on an average about these losses—

	In boiling.	In baking.	In roasting.
4 lb. of beef lose, .	1 lb.	1 lb. 3 oz.	1 lb. 5 oz.
4 lb. of mutton lose, .	14 oz.	1 lb. 4 oz.	1 lb. 6 oz.

The greater loss in baking and roasting arises chiefly from the greater quantity of water which is evaporated, and of fat which is melted out during these two methods of cooking. Two circumstances, however, to which it has not hitherto

been necessary to advert, have much influence upon the successful result of these and some other modes of cooking.

If we put moist flesh-meat into a press and squeeze it, a red liquid will flow out. This is water coloured by blood, and holding various saline and other substances in solution. Or if, after being cut very fine, or chopped very fine, the flesh be put into a limited quantity of clean water, the juices of the meat will be gradually extracted, and by subsequent pressure will be more completely removed from it than when pressure is applied to it in the natural state, and without any such mincing and steeping. The removal of these juices leaves the beef or mutton nearly tasteless.

When the juice of the meat extracted in either way is heated nearly to boiling, it thickens or becomes muddy, and flakes of whitish matter separate, which resemble boiled white of egg. They are, in fact, white of egg or albumen, and they show that the juice of flesh contains a certain quantity of this substance in the same liquid and soluble state in which it exists in the unboiled egg. Now, the presence of this albumen in the juice of butcher-meat is of much importance in connection with the skilful preparation of it for the table.

The first effect of the application of a quick heat to a piece of fresh meat is to cause the fibres to contract, to squeeze out a little of the juice, and to a certain extent to close up the pores so as to prevent the escape of the remainder. The second is to coagulate the albumen contained in the juice, and thus effectually and completely to plug up the pores, and to retain within the meat the whole of the internal juice. Thereafter, the cooking goes on through the agency of the natural moisture of the flesh. Converted into vapour by the heat, a kind of steaming takes place within the piece of meat, so that whether in the oven, on the spit, or in the midst of boiling water, it is in reality, when skilfully done, cooked by its own steam.

A well-cooked pi[illegible] neat should be full of its own juice or natural gravy. In roasting, therefore, it should be exposed to a quick fire, that the external surface may be made to contract at once, and the albumen to coagulate, before the juice has had time to escape from within. And so in boiling. When a piece of beef or mutton is plunged into boiling water,

the outer part contracts, the albumen which is near the surface coagulates, and the internal juice is prevented either from escaping into the water by which it is surrounded, or from being diluted and weakened by the admission of water into it. When cut up, therefore, the meat yields much gravy and is rich in flavour. Hence a beefsteak or a mutton-chop is done quickly, and over a quick fire, that the natural juices may be retained.

On the other hand, if the meat be exposed to a slow fire, its pores remain open, the juice continues to flow from within as it is dried from the surface, and the flesh pines and becomes dry, hard, and unsavoury. Or if it be put into cold or tepid water, which is afterwards gradually brought to a boil, much of the albumen is extracted before it coagulates, the natural juices for the most part flow out, and the meat is served in a nearly tasteless state. Hence, to prepare good boiled meat, it should be put at once into water already brought to a boil. But to make beef-tea, mutton-broth, or other meat-soups, the flesh should be put into the cold water, and this afterwards very slowly warmed, and finally boiled. The advantage derived from *simmering*, a term not unfrequent in cookery-books, depends very much upon the effects of slow boiling as above explained.

10°. Beef-tea.—It has lately been recommended to make beef-tea by simply chopping the meat small, pouring upon it its own weight, or any other desired quantity, of cold water, and bringing it quickly to a boil. This process extracts all the natural juices and gives a most agreeable and savoury tea, which holds in solution about one-eighth part of the solid substance of the beef. But it has been stated, as a recommendation of this process, *first*, that the tea obtained contains *all* the nutritive qualities of the meat, which is said to be no longer of any value; and, *secondly*, that it is as nutritious as if the meat were boiled long enough to give a tea which should stiffen to a jelly when cold.

But this statement is incorrect, and is made only in consequence of two very opposite things being confounded. The juice of the meat contains a small proportion of a substance called *kreatine*, which is rich in nitrogen, has a certain chemical relation to the peculiar principle of tea and coffee (*theine*)—of which I shall speak in a subsequent chapter—

and exercises, as I believe, a special tonic and exhilarating influence upon the system. This substance, with all the soluble salts (which are chiefly phosphate and chloride of potassium) of the flesh, the beef-tea made after the above process contains, and the residual fleshy fibre is tasteless, and will not alone support animal life for any length of time. But eaten along with the tea thus made, or with what the tea contains, or made into savoury meat by the addition of ordinary gravy, it will sustain and strengthen the body, as all experience proves. The meat-tea will perhaps be rather more nutritious, the more of the jelly-forming substance of the meat it holds in solution, though this gelatine is of much less value than albumen or fibrin. It will bear, in fact, to the thinner and more quickly made beef-tea, a similar relation to that which cocoa bears to the infusion of China tea.[1] Both of these last-named beverages contain a peculiar principle rich in nitrogen, which exercises a special influence on the activity of the brain; but the cocoa is rich besides in the substances which form our ordinary nourishment. And as, in consequence of this difference, cocoa is not so well suited as tea or coffee to the digestive powers of some constitutions, so it probably is with the meat-teas or decoctions prepared by the two processes referred to. The correct values, both relative and absolute, of the meat-teas made after the two methods, as well as of the undissolved residue of the meat, are therefore easily seen and understood. The extract of meat introduced by Liebig, is an excellent tonic and stimulant, in moderate doses, and aids the digestion of the true nutrients; but it is not in itself a true food, much less a perfect one. Some notion of the favour in which it is now held may be gained from the statement that 570,000 lb. of *extractum carnis* were produced in 1871 at a single establishment at Uruguay. To yield this quantity 122,075 cattle were slaughtered. 50 lb. of meat give 1 lb. extract.

11°. SALTING OF MEAT.—The application of salt to fresh meat has very much the same effect as the application of a quick heat. It causes the fibres to contract, the meat to lessen in bulk, and the juice to flow out from its pores. Hence the reason why dry salt strewed upon fresh lean meat gradually dissolves into a fluid brine. The effect of the salt,

[1] See "The Beverages we Infuse."

if a large quantity be applied, penetrates deep, so that as much as one-third of the juice of the meat is often forced out by the contraction of the fibres. The effect of this upon the meat is twofold. It diminishes the natural flavour, by removing a large proportion of the peculiar substances contained in the juice, and adding pure salt in their stead. At the same time it closes up the pores of the meat, and prevents the entrance of atmospheric air, thus diminishing the liability to decay.

The preservation of flesh-meat by salting, depends, therefore, upon the separation of water, upon the exclusion of air, upon the saturation with salt of the juice which remains in the meat, and upon the formation of a weak compound of the flesh with common salt, which does not readily undergo decay. But this preservation is attended by a diminution in its nutritive qualities, for the juice which flows out contains albumen (white of egg), kreatine, phosphoric acid, and potash. These substances are precisely the same as are more fully extracted by water, in the method of making savoury beef-tea, already described; and in proportion as they are extracted they diminish the nutritive properties of the meat. Hence one reason why long feeding on salt meat affects the health, and why vegetable and other substances which are capable of supplying what the meat had lost, are found to be the best means of restoring it. These vegetables contain potash-salts and but little common salt. We cannot live on them alone without adding common salt. So, on the other hand, we cannot maintain our health on salted meats unless we restore the potash-salts which they drive out of the body.

As a whole, flesh-meat is eminently nutritious, because it contains *all* the materials which are necessary to build up our own flesh; but remove from it a portion of these materials, and the remainder becomes more or less useless,—as bricks and stone become useless to the builder if we refuse him the requisite quantity of mortar.

12°. The Fat of Animal and Vegetable Substances.—We have seen that, as a whole, there is much analogy between the bread and the beef,—the vegetable and the animal forms of food on which we live. Between the gluten of the one and the fibrin of the other, we have also found a very close similarity, and that in the animal economy they are both

fitted and intended to serve the same main purpose. If we compare the fatty portions of both, we find new resemblances.

Most of the varieties of fat yielded by our common European vegetables are fluid and oily at ordinary temperatures. Such is the case with the fat extracted from linseed and poppy-seed, from the olive, the walnut, &c. The fat of the oil-palm, however, commonly known by the name of palm-oil, and some other vegetable fats or butters, are solid in the natural state, and at ordinary temperatures. And even the oily fats (olive-oil for example), when exposed to a low temperature, congeal or freeze to a certain extent, and allow of the separation of a solid fat in a greater or less proportion. On the other hand, those which are solid yield to pressure a quantity of a liquid fatty oil. So that in reality all vegetable fats consists of at least two fatty substances, one of which is solid, and the other liquid, at ordinary temperatures.

Now the same is the case with the animal fats—with those of beef and mutton for example, with the butter of milk, and with the oil contained in the yolk of the egg. All consist of a solid and a liquid fat, and in this fact we see a new analogy between our vegetable and our animal food.

But a still further and more intimate analogy exists between the solid portions of the fatty substances of the animal and vegetable kingdoms. When the solid fat of palm-oil is properly purified it is found to consist of a solid, beautifully white, peculiar fatty body, to which the name of *palmitin* has been given. On the other hand, when beef and mutton fats are pressed from the oil they contain, and then purified, the most abundant substance obtained is a peculiar fat which is known by the name of *stearin*. The remainder consists principally of palmitin.

Now, of these two fatty bodies the solid fat of all our domestic animals almost entirely consists. In beef and mutton fats the stearin is the more abundant. In human fat, in that of the goose, and in that of butter, the palmitin occurs in large quantity. It is the same with vegetable fats. They consist of these two varieties in different proportions. In some, the solid part consists chiefly of stearin; in others, as in olive-oil, the stearin and palmitin are nearly equal in quantity; while in others again, as in palm-oil, the palmitin is the principal ingredient. Thus, as there is a kind of iden-

tity in nutritive quality and value among the compounds represented respectively by gluten in plants and by fibrin in animals, so there is an absolute identity of substance—as regards their solid part at least—among the fatty compounds which are met with in the eatable productions of both kingdoms. There are several other solid fatty substances found in various vegetable and animal products, but they are all closely related to those above named.

The liquid portions of the fats of animals and vegetables consist in great measure of an oily substance called *olein.* They usually absorb oxygen freely from the air, and become hard, as in the drying oils—or rancid, as in those oils which do not harden. Fat meat keeps longer, when salted, if the fat be hard. And hence the reason why, in finishing off fat animals for the butcher, especially if they are to be salted, it is usual to give dry food for some time before killing, that the fat may be hardened and the flesh made firm.

It may be conveniently stated here that all the constituents of oils and fats above named, and many others as well, are known to chemists under the name of *glycerides.* These are compounds which, when acted on by water, are resolved into the sweet substance called glycerine, and various fatty acids —stearic, palmitic, oleic, &c.

In another matter I might show how, in still more minute details, animal and vegetable kinds of food are nearly identical. When the parts of plants are burned in the open air they disappear for the most part, as I have already shown,[1] and leave only a small proportion of ash behind. This ash consists of a mixture of various substances, spoken of as their mineral, earthy, saline, or inorganic constituents.

The same takes place when the parts of animals are burned; and the mixture of mineral matters obtained consists, in either case, of the same substances, only differing more or less in their relative proportions. The same things occur in the ash of bread as are found in the ash of beef. In whatever degree, therefore, the nutritive properties of our food depend upon the kind of mineral matter it contains, it is almost a subject of indifference whether we live upon an animal or a vegetable diet.

But to this interesting point I shall have occasion to return in a subsequent chapter.

[1] See "The Plant we Rear," p. 54.

CHAPTER VII.

THE BEVERAGES WE INFUSE.

THE TEAS.

Artificial drinks nearly all vegetable infusions, with or without subsequent chemical changes.—Tea, extensive use of.—The tea-plant; how its leaves are gathered.—The aroma produced by roasting.—Mode of preparing green and black teas from the same leaves.—Principal varieties of green and black teas.—Differences in fragrance and flavour.—Ancient use of tea in China and the adjoining countries.—Introduction into Europe.—Total amount of tea produced.—Consumption in the United Kingdom.—Sensible effects of tea.—Active chemical ingredients in tea.—The volatile oil, its action.—The theine, its composition.—Occurs in coffee, in maté, in kola, and in guarana.—Its effect in retarding the waste of the tissues.—Why tea is a favourite with the poor.—The tannin, its properties and effects.—The gluten.—Tea-leaves and beans compared in nutritive quality.—Tartar mode of using tea.—Eating the exhausted leaves.—Tea varies in composition.—Proportion extracted by water varies.—How tea is coloured or dyed green in China.—Lie tea.—Maté or Paraguay tea; its ancient use in South America.—The *Ilex paraguayensis* or maté-tree, where it grows, and how its leaves are collected.—Gongonha of Brazil, a variety of maté.—Frequent use of maté, and its effects.—Composition of the leaf.—The volatile oil, the theine, the tannic acid, and the gluten.—Coffee-tea made from the leaf of the coffee-tree; use of this tea in the Eastern Archipelago; effects observed from its use in Sumatra; contains the same active ingredients as the leaves of the tea-trees.—Labrador tea used in North America.—Abyssinian tea or ckaat.—Tasmanian teas.—Faham tea.—Table of substitutes for Chinese tea and for maté.

The two most important natural liquids, water and milk, have already been treated of. Various artificial drinks, however, are prepared both in civilised and in semi-barbarous countries, and are in daily use among vast multitudes of men. Such

are tea, coffee, and cocoa, beer, wine, and ardent spirits. The preparation and effects of each of these are connected with interesting chemical considerations.

These drinks agree in being all prepared from or by means of substances of vegetable origin, and in being generally classed among the luxuries rather than the necessaries of life.

The mode in which they are prepared, however, naturally divides them into two classes. Tea, coffee, and cocoa are roasted and prepared before they are infused in water, and the infusion is then drunk without further chemical treatment. These are simply *infused* beverages. Beer, wine, and ardent sprits are prepared from infusions which, after being made, are subjected to important chemical operations. Among these operations is the process of fermentation, and hence they are properly distinguished as *fermented* liquors.

I shall therefore consider these two classes of drinks separately, and in the order in which I have mentioned them.

The infused beverages are drunk hot, fermented drinks are usually taken cold. The love of such warm drinks prevails almost universally. In frozen Labrador and snowy Russia, the climate might account for this predilection, but the craving is really deeper seated. The practice prevails equally in tropical and in arctic regions. In Central America, the Indian of native blood and the Creole of mixed European race indulge alike in their ancient chocolate. In Southern America the tea of Paraguay is an almost universal beverage. The native North American tribes have their Appalachian tea, their Oswego tea, their Labrador tea, and many others. From Florida to Georgia, in the United States, and over all the West India Islands, the naturalised European races sip their favourite coffee; while over the Northern States of the Union, and in the British provinces, the tea of China is in constant and daily use.

All Europe, too, has chosen its prevailing beverage. Spain and Italy delight in chocolate; France and Germany, and Sweden and Turkey, in coffee; while Russia, Holland, and England are particularly partial to tea.

All Asia feels the same want, and in different ways has long gratified it. Coffee, indigenous in Abyssinia, has spread to the adjoining countries, and has followed the banner of the Prophet, wherever in Asia or Africa his false faith has

triumphed. Tea, a native of Bengal, and possibly also of parts of China, has spread spontaneously over the hill-country of the Himalayas, the table-lands of Tartary and Thibet, and the plains of Siberia—has climbed the Altais, overspread all Russia, and is equally despotic in Moscow as in St Petersburg. In Sumatra, the coffee-leaf yields the favourite tea of the dark-skinned population, while Central Africa boasts of the Abyssinian *kaat* as the indigenous warm drink of its Ethiopian peoples. Everywhere unintoxicating and non-narcotic beverages are in general use,—among tribes of every colour, beneath every sun, and in every condition of life. The custom, therefore, must meet some universal want of our poor human nature.

The beverages we infuse naturally arrange themselves into three classes. First, the *teas* or infusions of leaves; second, the *coffees* or infusions of seeds; and third, the *cocoas*, which are more properly soups or gruels than simple infusions, as they are made by diffusing, through boiling water, the entire seeds of certain plants previously ground into a paste.

THE TEAS.—Of teas there are many varieties in use in different parts of the world; but China tea, Paraguay tea or maté, and perhaps coffee-tea, are the most extensively consumed as national beverages. There are some others in constant though less general employment, to which it will be necessary somewhat briefly to advert.

I. CHINA TEA is not only the most important of these beverages to the British and other English-speaking peoples, but it forms the daily drink of a larger number of men than all the others put together. Among the two hundred and fifty millions of China, and among the inhabitants of Japan, Thibet, and Nepaul, it is an article of consumption with all classes three or four times a-day. In Asiatic Russia also, in a large proportion of Europe, in North America, and in Australasia, it is in, or is coming into, almost equally extensive use. It is consumed at the present moment by probably not less than five hundred millions of men, or more than one-third of the whole human race!

The tea-plant (*Thea sinensis*) has much resemblance to the Camellia japonica. There are several varieties of it, dis-

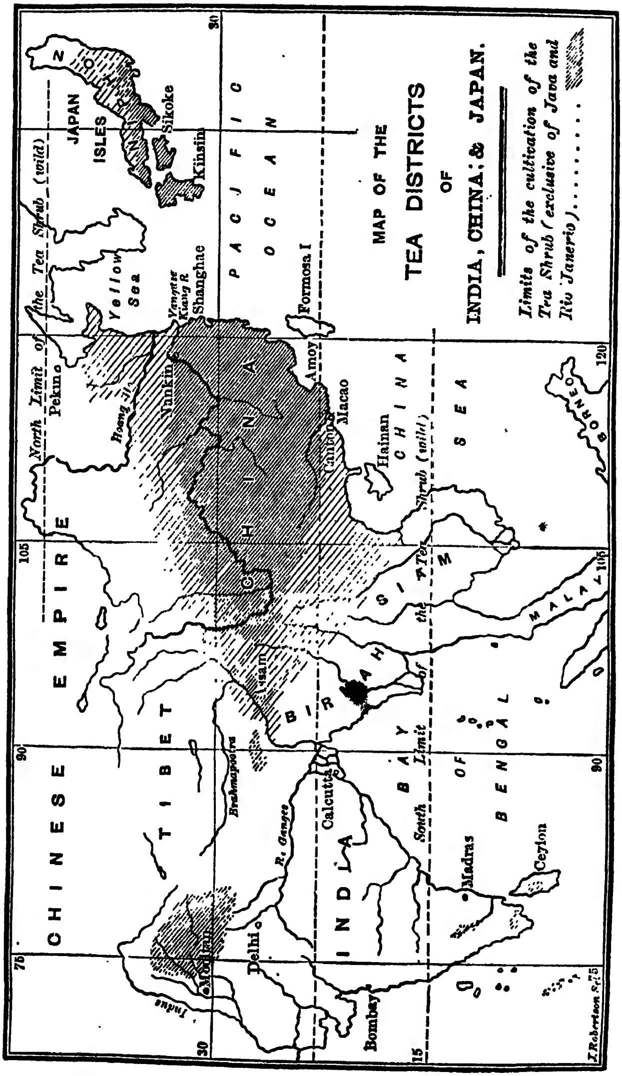

MAP OF THE
TEA DISTRICTS
OF
INDIA, CHINA, & JAPAN.
Limits of the cultivation of the Tea Shrub (exclusive of Java and Rio Janerio)........
North Limit of the Tea Shrub (wild)
South Limit of the Tea Shrub (wild)
CHINESE EMPIRE
TIBET
CHINA
JAPAN ISLES
Sikoke
Kinsin
Yellow Sea
PACIFIC OCEAN
Formosa I
Shanghae
Pekin
Amoy
Macao
Hainan
CHINA SEA
SIAM
BAY OF BENGAL
INDIA
Calcutta
Madras
Ceylon
Bombay
Delhi
Brahmapootra
R. Ganges
Indus
BORNEO
75
90
105
120
30
15

Fig. 21.

Thea sinensis, var. *bohea* —The Bohea Tea-plant.
Scale, 1 inch to 5 feet.
Scale for leaf, 1 inch to 2 inches.

tinguished by some botanists as the *Thea viridis*, *T. bohea*, and *T. stricta*, but all are now recognised as belonging to one single species, somewhat altered in habit and appearance by cultivation, climate, and soil. The two most marked varieties are represented by the annexed woodcuts. The smaller (fig. 21) is the *Thea sinensis*, var. *bohea*, which produces the inferior green and black teas which are made about Canton. The larger (fig. 22) is the *Thea sinensis*, var. *viridis* — the more northern variety, from which are made all the fine green teas in the great Hwuychow and adjoining provinces. The plant is believed to be a native of Bengal, but it appears to grow wild among the hills of China. It thrives best in the cooler parts of the tropical zone, but grows in the temperate zone even as far north as the 40th degree of north latitude. The districts of China which supply the greater portion of the teas exported to Europe and America lie between the 25th and the 31st degrees of north latitude, and the best districts are those between 27° and 31°.—(Fortune.)

Fig. 22.

Thea sinensis, var. *viridis*—The Green Tea-plant.
Scale. 1 inch to 5 feet.
Scale for leaf, 1 inch to 2 inches.

The tea-plants are raised from seed which, to secure germination, is kept over winter in moist earth, and sown in March. When a year old, the young bushes are planted out, and then by cropping the main shoot for the first year they are kept down to a height of about 3 feet, and made to grow bushy. Being placed in rows 3 or 4 feet apart, they have some resemblance to a garden of gooseberry-bushes. The cropping of the leaves begins

in the fourth and fifth years, and is seldom continued beyond the tenth or twelfth, when the bushes are dug up and renewed. The plant thrives best on dry sunny slopes, where occasional showers fall and springs appear, and where an open, somewhat stony but rich soil, prevents the water from lingering about its roots. The season for gathering varies in different districts, but the principal leaf-harvest ends in May or June. The leaves are plucked by the hand, and chiefly by women. They are generally gathered at three successive seasons. The youngest and earliest leaves are the most tender and delicate, and give the best-flavoured tea. The second and third gatherings are more bitter and woody, and yield less soluble matter to water. The refuse and decayed leaves and twigs are pressed into moulds and sold under the name of brick-tea. These bricks are often made harder by mixing the leaves with the serum of sheep and ox blood. This inferior variety is chiefly consumed in northern China and Thibet. In western China the leaves of a coarse tea-plant are picked in June and July, slightly fermented, and then pressed into "bricks," of which about 6,000,000 lb. are yearly exported into Thibet.

The first in order, and not the least interesting point, in the chemical history of the tea we use, is the mode in which it is prepared for the market. The leaves when freshly plucked have neither a decidedly astringent, an aromatic, nor a bitter taste. They possess nothing, in fact, either of the odour or flavour of the dried leaves. The pleasant taste and delightful natural scent for which they are afterwards so highly prized, are all developed by the roasting which they undergo in the process of drying. The details of this process were first made known to us through the investigations of Mr Fortune.

Another interesting chemical fact is, that different qualities of tea are prepared from the same leaves, according to the way in which they are treated in the drying. This we should expect to a certain extent. But the inquiries of Mr Fortune have shown that either green or black tea—though these varieties are so unlike each other—may be prepared at will from the same leaves, gathered at the same time and under the same circumstances. The mode of drying and roasting the leaves generally, and the specific processes by which the green and the black teas are severally obtained, have been

minutely described by Mr Fortune;[1] and from his description we learn—

First, That in the process of drying, the leaves are fer-

[1] His description is as follows:—

For Green Tea.—When the leaves are brought in from the plantations they are spread out thinly on flat bamboo trays, in order to dry off any superfluous moisture. They remain for a very short time exposed in this manner, generally from one to two hours; this, however, depends much upon the state of the weather.

In the meantime the roasting-pans have been heated with a brisk wood-fire. A portion of leaves is now thrown into each pan, and rapidly moved about and shaken up with both hands. They are immediately affected by the heat, begin to make a crackling noise, and become quite moist and flaccid, while at the same time they give out a considerable portion of vapour. They remain in this state for four or five minutes, and are then drawn quickly out and placed upon the rolling-table, and rolled with the hands.

Having been thrown again into the pan, a slow and steady charcoal-fire is maintained, and the leaves are kept in rapid motion by the hands of workmen. Sometimes they are thrown upon the rattan-table and rolled a second time. In about an hour, or an hour and a half, the leaves are well dried, and their colour has become *fixed*,—that is, there is no longer any danger of their becoming black. They are of a dullish-green colour, but become brighter afterwards.

The most particular part of the operation has now been finished, and the tea may be put aside until a larger quantity has been made. The second part of the process consists in winnowing and passing the tea through sieves of different sizes, in order to get rid of the dust and other impurities, and to divide the tea into the different kinds known as twankay, hyson-skin, hyson, young hyson, gunpowder, &c. During this process it is re-fired—the coarse kinds once, and the finer sorts three or four times. By this time the colour has come out more fully, and the leaves of the finer kinds are of a dull bluish green.

For Black Tea.—When the leaves are brought in from the plantations they are spread out upon large bamboo mats or trays, *and are allowed to lie in this state for a considerable time.* If they are brought in at night, they lie until next morning.

The leaves are next gathered up by the workmen with both hands, thrown into the air, and allowed to separate and fall down again. They are tossed about in this manner, and slightly beaten or patted with the hands, for a considerable space of time. At length, when they become soft and flaccid, they are thrown in heaps, and *allowed to lie in this state for about an hour or perhaps a little longer.* When examined at the end of this time, they appear to have undergone a slight change in colour, are soft and moist, and emit a fragrant smell.

The rolling process now commences. Several men take their stations at the rolling-table, and divide the leaves amongst them. Each takes as many as he can press with his hands, and makes them up in the form of a ball. This is rolled upon the rattan-worked table, and greatly compressed, the object being

mented, roasted, and scorched in such a way as necessarily to bring about many chemical changes within the substance of the leaves themselves. The result of these changes is to produce the varied flavours, odours, and tastes by

to get rid of a portion of the sap and moisture, and at the same time to twist the leaves. These balls of leaves are frequently shaken out, and passed from hand to hand until they reach the head workman, who examines them carefully to see if they have taken the requisite twist. When he is satisfied of this, the leaves are removed from the rolling-table and shaken out upon flat trays, until the remaining portions have undergone the same process. In no case are they allowed to lie long in this state, and sometimes they are taken at once to the roasting-pan.

The next part of the process is exactly the same as in the manipulation of green tea. The leaves are thrown into an iron pan, where they are roasted for about five minutes, and then rolled upon the rattan-table.

After being rolled, the leaves are shaken out, thinly, on sieves, and exposed to the air out of doors. A framework for this purpose, made of bamboo, is generally seen in front of all the cottages among the tea hills. The leaves are allowed to remain in this condition for about three hours: during this time the workmen are employed in going over the sieves in rotation, turning the leaves and separating them from each other. A fine dry day, when the sun is not too bright, seems to be preferred for this part of the operation.

The leaves having now lost a large portion of their moisture, and having become considerably reduced in size, are removed into the factory. They are put a second time into the roasting-pan for three or four minutes, and taken out and rolled as before.

The charcoal-fires are now got ready. A tubular basket, narrow at the middle and wide at both ends, is placed over the fire. A sieve is dropped into this tube, and covered with leaves, which are shaken on it to about an inch in thickness. After five or six minutes, during which time they are carefully watched, they are removed from the fire and rolled a third time. As the balls of leaves come from the hands of the rollers, they are placed in a heap until the whole have been rolled. They are again shaken on the sieves as before, and set over the fire for a little while longer. Sometimes the last operation—namely, heating and rolling—is repeated a fourth time: the leaves have now assumed a dark colour.

When the whole have been gone over in this manner, they are placed thickly in the baskets, which are again set over the charcoal-fire. The workman now makes a hole with his hand through the centre of the leaves, to allow vent to any smoke or vapour which may rise from the charcoal, as well as to let up the heat, which has been greatly reduced by covering up the fires. The tea now remains over the slow charcoal-fire, covered with a flat basket, until it is perfectly dry,—carefully watched, however, by the manufacturer, who every now and then stirs it up with his hands, so that the whole may be equally heated. The black colour is now fairly brought out, but afterwards improves in appearance. The after-processes, such as sifting, picking, and refining, are carried on at the convenience of the workmen.

which different varieties of tea are more or less distinguished.

Secondly, That the treatment or mode of handling by which the leaves are converted respectively into green and black teas, is the cause of the different colours of these two main varieties. Thus, for

Green Teas.	*Black Teas.*
1°. The leaves are roasted almost immediately after they are gathered.	1°. They are allowed to be spread out in the air for some time after they are gathered.
2°. They are dried off quickly after the rolling process. The whole operation is speedy and simple.	2°. They are then further tossed about till they become soft and flaccid.
	3°. They are now roasted for a few minutes, and rolled; after which they are exposed to the air for a few hours in a soft and moist state.
	4°. Lastly, they are dried slowly over charcoal-fires.

It is by lengthened exposure to the air, therefore, in the process of drying, accompanied by a slight heating and fermentation, that the dark colour and distinguishing flavour are given to the black teas of commerce. The oxygen of the atmosphere acts rapidly upon the juices of the leaf during this exposure, and changes chemically the peculiar substances they contain, so as to impart to the entire leaf the dark hue it finally acquires.

This action of the air does not appear sensibly to affect the weight of the tea obtained, as three pounds of the fresh leaves produce on an average about one pound of marketable tea of either kind. The teas intended for home consumption are not so highly dried as those which are prepared for exportation—(Bowring)—a circumstance which must affect the quality of the beverage they yield.

The produce of different districts varies in quality and flavour with the climate, the soil, and the variety of plant cultivated, as well as with the period at which the leaves are gathered, and with the mode of drying them. The finest tea of China grows between the 27th and 31st parallels of north latitude, on a low range of hills, which is an offshoot of

the great chain of Pe-ling. The principal varieties of *black* tea are known by the names of Bohea, Congou, Campoi, Souchong, Caper, and Pekoe. Of these the bohea grows in the province of Fu-kian (Fokien). Pekoe, or pak-ho, means "white down" in Chinese, and consists of the first downy sprouts or leaf-buds of three-year-old plants. A very costly tea of this kind, known as the "Tea of the Wells of the Dragon," is used only by persons of the highest rank in China, and is never brought to Europe. Caper is in hard grains, made up of the dust of the other varieties cemented together by means of gum. The *green* teas are known as Twankay, Hyson-skin, Hyson, Imperial, and Gunpowder. The hyson is grown in the province of Song-ho. The true imperial, known also, because of its excellence, as the flos-theae, seldom comes to Europe,—that which is usually sold under this name being really Chusan tea flavoured with the cowslip-coloured blossoms of the sweet-scented olive (*Olea fragrans*). The practice of scenting teas is very common, and various odoriferous plants are employed for the purpose in different parts of China.[1] It is remarked, however, by the dealers in tea, that the plantations which naturally yield a produce of a particularly esteemed flavour are as limited in extent as the vineyards in Europe which are celebrated for particular kinds of wine. The price of tea varies, of course, with the variations in natural quality, being for some samples double or treble what is asked for others. But the average price at Canton is about 8½d. a pound, so that the grower must sell it at 5d. or 6d.—(Meyen.)

Tea-leaves, prepared as above described, have been in use as a beverage in China from very remote periods. Tradition speaks of it as early as the third century. The legend relates, "that a pious hermit, who in his watchings and prayers had often been overtaken by sleep, so that his eyelids closed, in holy wrath against the weakness of the flesh, cut them off and threw them on the ground. But a god caused a tea-shrub to spring out of them, the leaves of which exhibit

[1] Among these are mentioned the Olea fragrans, Chloranthus inconspicuus, Gardenia florida, Aglaia odorata, Mogorium sambac, Vitex spicata, Camellia sasanqua, Camellia odorifera, Illicium anisatum, Magnolia gracilis, Rosa indica odoratissima, Murraya exotica, turmeric, oil of Bixa orellana, and the root of the Florentine Iris. With such a list before us, we cannot wonder that teas should exhibit great diversity in fragrance and flavour.

the form of an eyelid bordered with lashes, and possess the gift of hindering sleep." A similar story is related concerning the introduction of coffee into Arabia. Both legends were probably invented long after the qualities of tea and coffee were known.

It was after the year 600 that the use of tea became general in China, and early in the ninth century (810) it was introduced into Japan. To Europe it was not brought till about the beginning of the seventeenth century. Hot infusions of leaves had been already long familiar as drinks in European countries. Dried sage-leaves were much in use in England,[1] and are even said to have been carried as an article of trade to China by the Dutch, to be there exchanged for the Chinese leaf, which has since almost entirely superseded them. A Russian embassy to China also brought back to Moscow some carefully-packed green tea, which was received with great acceptance. In 'Pepys' Diary' for 1660, we have one of the earliest accounts of its use in this country; and soon after (1664), the English East India Company considered it as a rare gift to present the queen of Charles II. of England with two pounds of tea! In 1745 the consumption was but 730,000 lb. per annum; yet it must then have come into pretty general use, for in the correspondence of Duncan Forbes, which dates from 1715-48, occurs the following passage: "The excessive use of tea, which is now become so common, that the meanest families, even of labouring people, particularly in boroughs, make their morning's meal of it, and thereby wholly disuse the ale which heretofore was their accustomed drink; and the same drug supplies all the labouring women with their afternoon's entertainments to the exclusion of the twopenny." These were the palmy days of Dr Johnson's tea-triumphs—the days in which he describes himself as "a hardened and shameless tea-drinker, who has for many years diluted his meals with only the infusion of this fascinating plant; whose kettle has scarcely time to cool; who with tea amuses the evenings, with tea solaces the midnights, and with tea welcomes the morning."

The growth and consumption of tea are now really enorm-

[1] Sage was in frequent use till after the middle of last century. In the life of Whitfield, it is stated that, when in his fasting humours at Oxford, "he ate nothing but sage-tea with sugar, and coarse bread." This was about 1730.

ous. Mr Ingham Travers estimated (in 1852) the total produce of the dried leaf in China alone at a million of tons, or 2240 millions of pounds! To this is to be added the tea of Japan, Corea, Assam, and Java. The produce of this latter island already goes far to supply the markets of Holland; and the introduction of the tea-plant into the hill-country of India, into Pulo Penang on the Malacca coast, into Rio Janeiro, and since 1868 into Ceylon, adds largely to the present growth. In 1857 there were but 121,000 lb. of tea exported from British India; while the amount exceeded 17,000,000 lb. in 1872, and in 1877 31,000,000 lb. were imported into this country. If we take the quantity of tea yielded by an acre of land at 600 lb., which is probably a full estimate, the extent of land devoted to this branch of rural industry in China alone must be nearly 3½ millions of acres!

The consumption of tea in the United Kingdom in 1853 amounted to 58 millions of pounds (25,000 tons)—about one forty-fifth part of the estimated produce of China at that time. This is at the rate of 2 lb. per head of the population. If we go back to 1835 we find that the amount was not quite 1½ lb. per head; while in 1877 it was close upon 4½ lb., or three times as much. In 1871 it amounted to 123½ millions of pounds, or 3 lb. 15 oz. per head. In 1876 the total import of tea nearly reached 186 millions of pounds. The quantities actually consumed in this country may be taken as about—

32,000,000 lb. in 1840.	77,000,000 lb. in 1860.
51,000,000 ,, in 1850.	118,000,000 ,, in 1870.

Among European nations, tea is pre-eminently a British, Dutch, and Russian drink. Among the other nations of Europe, coffee and cocoa are more usual beverages than tea. This is strikingly illustrated by the fact, that while in 1835 about 36,000,000 lb. of tea were consumed in the United Kingdom, only 200,000 lb. were consumed in the kingdom of Prussia! The population of Prussia was then upwards of thirteen millions. And this difference in national tastes and habits is further illustrated by the actual present consumption of tea and coffee in England, France, and Germany.

The effects of tea, as it is used in China, are thus described by Chinese writers: "Tea is of a cooling nature, and, if drunk too freely, will produce exhaustion and lassitude.

Country people, before drinking it, add ginger and salt to counteract this cooling property. It is an exceedingly useful plant. Drink it, and the animal spirits will be lively and clear. The chief rulers and nobility esteem it; the lower people, the poor and beggarly, will not be destitute of it. All use it daily, and like it." Another writer says, "Drinking it tends to clear away all impurities, drives off drowsiness, removes or prevents headache, and is universally in high esteem."[1]

The mode of using it in China is to put the tea into a cup, to pour hot water upon it, and then to drink the infusion off the leaves, and without admixture. While wandering over the tea districts of China, Mr Fortune only once met with sugar and a teaspoon.

The mode of making and drinking the infusion of tea probably does not alter its general effects upon the system. In China cold water is disliked, and considered as unwholesome, and therefore tea is taken to quench the thirst, which it probably does best when drunk unmixed. The universal use, on the other hand, of sugar and cream or milk among us, probably arose from its being introduced here as a beverage among grown-up people whose tastes were already formed, and who required something to make the bitter infusion palatable. The practice thus begun has ever since continued, and, physiologically considered, is on the whole, I believe, an improvement upon the Eastern fashion.

In Russia, a squeeze of a lemon often takes the place of our cream; and in Germany, where the tea is made very weak, it is common to flavour it with rum, cinnamon, or vanilla. In Spain, a few leaves of the lemon-verbena (*Aloysia citriodora*) are placed in the cup, and the hot tea poured over them.

The effects of tea as obtained and thus used among us are too familiarly known to require any detailed explanation. It exhilarates without sensibly intoxicating. It excites the brain to increased activity, and produces wakefulness. Hence its usefulness to hard students, to those who have vigils to keep, and to persons who labour much with the head. It soothes, on the contrary, and stills the vascular system, and hence its use in inflammatory diseases, and as a cure for headache. Green tea, when taken strong, acts very powerfully

[1] Fortune's Tea Countries of China, vol. ii. p. 231.

upon some constitutions, producing nervous tremblings and other distressing symptoms, acting as a narcotic, and in inferior animals even producing paralysis.[1] Its exciting effect upon the nerves makes it useful in counteracting the effects of opium and of fermented liquors, and the stupor sometimes induced by fever.

In manufactured tea there are at least three active chemical substances, by the conjoined influence of which these effects are produced.

1°. *The Volatile Oil.*—When commercial tea is distilled with water, there passes over a small quantity of a volatile oil, which possesses the aroma and flavour of the tea in a high degree. A hundred pounds of tea often yield less than half a pound of this oil, and to this minute quantity of its volatile ingredient the value of tea in general estimation is in a great measure due. Its special action upon the system has not yet, we believe, been scientifically investigated. But that it does exercise a powerful, and most likely a narcotic influence, is rendered probable by many known facts. Among these I mention the headaches and giddinesses to which tea-tasters are subject; the attacks of paralysis to which, after a few years, those who are employed in packing and unpacking chests of tea are found to be liable; and the circumstance already alluded to, that in China tea is rarely used till it is a year old, because of the peculiar intoxicating property which new tea possesses. The effect of this keeping upon tea must be chiefly to allow a portion of the volatile ingredients of the leaf to escape. And lastly, that there is a powerful virtue in this oil is rendered probable by the fact, that the similar oil of coffee has been found by experiment to possess narcotic properties, as we shall see further on.

This volatile ingredient does not exist in the natural leaf, but is produced during the process of drying and roasting already described.

2°. *The Theine.*—When dry finely-powdered tea-leaves are put upon a watch-glass, covered over with a conical cap of paper, and then placed upon a hot plate, a white vapour gradually rises from the leaves, and condenses on the inner side of the paper in the form of minute colourless crystals.

[1] New tea in China is said to exhibit this narcotic quality in a high degree, and hence the Chinese rarely use tea before it is a year old.

If, instead of the leaves, a dried watery extract of the leaves be employed, the crystals will be obtained in greater abundance. These crystals consist of the substance known to chemists by the name of Theine or Caffeine. The teas of commerce contain, on an average, about two per cent of this theine—(STENHOUSE). In some it is a little more. Certain green teas, according to Péligot, contain as much as six pounds in every hundred pounds of the dried tea; but so large a proportion as this is very rare.

Theine has no smell, and only a slightly bitter taste. It has little to do, therefore, either with the taste or flavour of the tea from which it is extracted. It is remarkable, however, in three respects—

First, in containing a very large percentage of nitrogen, an element I have already spoken of as forming four-fifths of the bulk of our common atmospheric air, and as distinguishing the gluten of wheat from the starch with which it is associated in the grain.[1] The percentage composition of theine is represented by the following numbers—

Carbon,	49.5
Hydrogen,	5.1
Nitrogen,	28.9
Oxygen,	16.5
	100.0

It contains, therefore, nearly three-tenths of its weight of nitrogen; a proportion which exists in only a very small number of other known substances.

Secondly, Theine is remarkable in being present not only in Chinese tea, but also in maté or Paraguay tea, in coffee, and in guarana—a substance prepared and used in Brazil in the same way as coffee: it has also been found in the kola-nuts of Africa. It is a very curious fact that, in countries so remote from each other, plants so very unlike as all these are, should have been, by a kind of instinct as it were, selected for the same purpose of yielding a slightly exciting, exhilarating, and refreshing beverage; and that these plants, when now examined by chemists, should all be found to contain the same remarkable compound body which we call theine or caffeine. The selection must have been made by the independent discovery, in each country, and by each people, that

[1] See "The Air we Breathe" and "The Bread we Eat."

these several plants were capable of gratifying a natural constitutional craving, or of supplying a want equally felt by all.

Thirdly, The observed effects of this substance, when introduced into the system, justify this conclusion, and form the third point which is worthy of remark in regard to it. It is known that the animal body, while living, undergoes constant decay and renovation. The labours of life waste it—the food introduced into the stomach renews it. That which is wasted passes off through the lungs and the kidneys, or is in other ways rejected from the body of the animal. The solid matters contained in the urine are in some degree a measure of this waste; and especially the quantity of urea and phosphoric acid it contains at different periods, is supposed to measure the comparative waste of certain constituents of the blood and the tissues at these different times. Now, the introduction into the stomach of even a minute proportion of theine—three or four grains a-day—has the remarkable effect of sensibly diminishing the absolute quantity of these substances voided in a day by a healthy man, living on the same kind of food, and engaged in the same occupation, under the same circumstances. This fact seems to indicate that the waste of the body is lessened by the introduction of theine into the stomach—that is, by the use of tea. And if the waste be lessened, the necessity for food to repair it will be lessened in an equal proportion. In other words, by the consumption of a certain quantity of tea, the health and strength of the body will be maintained in an equal degree upon a smaller supply of ordinary food. Tea, therefore, saves food—stands to a certain extent in the place of food—while at the same time it soothes the body and enlivens the mind.

In the old and infirm it serves also another purpose. In the life of most persons a period arrives when the stomach no longer digests enough of the ordinary elements of food, to make up for the natural daily waste of the bodily substance. The size and weight of the body, therefore, begin to diminish more or less perceptibly. At this period tea comes in as a medicine to arrest the waste, to keep the body from falling away so fast, and thus to enable the less energetic powers of digestion still to supply as much as is needed to repair the wear and tear of the tissues.

No wonder, therefore, that tea should be a favourite—on the one hand, with the poor, whose supplies of substantial food are scanty—and on the other, with the aged and infirm, especially of the feebler sex, whose powers of digestion and whose bodily substance have together begun to fail. Nor is it surprising that the aged female, who has barely enough of weekly income to buy what are called the common necessaries of life, should yet spend a portion of her small gains in purchasing her ounce of tea. She can live quite as well on less common food, when she takes her tea along with it; while she feels lighter at the same time, more cheerful, and fitter for her work, because of the indulgence.

The quantity of three or four grains of theine, mentioned above, is contained in less than half an ounce of good tea, and may be taken in a day by most full-grown persons, without unpleasant effects. But if twice this quantity, or eight grains a-day, be taken, the pulse becomes more frequent, the heart beats stronger, trembling comes on, and a perpetual desire to void urine. At the same time the imagination is excited, and, after a while, the thoughts wander, visions begin to be seen, and a peculiar state of intoxication comes on. All these symptoms are followed by, and pass off in, a deep sleep. The effects of strong tea, therefore—and especially of old teas, and such as are peculiarly rich in theine—are to be ascribed in great part to the over-dose of this substance which has been introduced into the stomach.

3°. *The Tannin*, or *Tannic Acid.*—If tea be infused in hot water in the usual manner and the infusion be poured into a solution of common green copperas (sulphate of iron), the mixture will become black. Or if it be poured into a solution of glue or isinglass (gelatine), it will render the solution turbid or muddy, and cause a greyish precipitate to fall. These appearances show that the tea contains an astringent substance, known to chemists by the name of tannin, or tannic acid. This substance is so called, because it is the ingredient which, in oak-bark, is so generally employed for the tanning of leather.

To this tannic acid tea owes its astringent taste, its constipating effect upon the bowels, and its property of giving an *inky* infusion with water which contains iron. It forms from 13 to 18 per cent of the whole weight of the dried tea-

leaf, and is the more completely extracted the longer the tea is infused. The tannic acids, of which many varieties are known to chemists, though naturally colourless, have all a tendency to become dark-coloured when exposed to the air. This is one reason why the same leaves, when dried quickly, will give a *green*, and when dried more slowly, a *black* tea, as has been described by Mr Fortune.

What is the full and precise action of this tannin upon the system, as we drink it in our tea, or whether it contributes in any degree to the exhilarating, satisfying, or narcotic action of tea, is not yet known. That it does aid even in the exhilarating effect which tea produces, is rendered very probable by the fact, that a species of tannin is the principal ingredient in the Indian betel-nut, which is so much chewed and prized in the East, and which is said to produce a kind of mild and agreeable intoxication.[1]

4°. *The Gluten.*—The three substances already described may be considered as the really active constituents of the tea-leaf as it is usually employed. But it is an interesting fact, that the leaf contains a large proportion of that nutritive ingredient of plants to which the name of gluten[2] is given. This substance forms as much as one-fourth of the weight of the dry leaves, or about the same quantity as in haricot-beans; so that if we chose to eat them in mass, they would prove as nutritious in that respect as pulse.

Of this large percentage of gluten, the water in which we usually infuse our tea extracts very little; and hence we throw away, in the waste leaves, a large proportion of the nutrients they contain. It has been recommended, therefore, as an improved method of infusing tea, that a pinch of soda should be put into the water along with it. The effect of this would be, that a portion at least of the gluten would be dissolved, and the beverage in consequence made more nutritious. The method of preparing the brick tea adopted among the Mongols and other Tartar tribes, is believed to extract the greater part of the nutriment from the leaf. They rub the tea to fine powder, boil it with the alkaline steppe-water, to which salt and fat or butter have been added, and pour off the decoction from the sediment. When the water is

[1] See "The Narcotics we Indulge in."
[2] See "The Bread we Eat."

not naturally alkaline they add soda, as is usual in Thibet. There brick tea is much used. Of this liquid they drink from 20 to 40 cups a-day, mixing it first with milk, butter, and a little roasted meal. But even without meal, and mixed only with a little milk, they can subsist upon it for weeks in succession.

The effect of the tea in this way of using it seems to be twofold. *First*, it directly nourishes by the gluten and milk or meal it contains; and, *secondly*, it makes this food go farther, through the waste-retarding influence of the theine, which the boiling thoroughly extracts.

But the most perfect way of using tea is that described, I think, by Captain Basil Hall, as practised on the coast of South America, where tea-leaves, after being exhausted by infusion, are handed round the company upon a silver salver, and partaken of by each guest in succession. The exhilarating effects of the hot liquid are in this practice followed by the nutritive effects of the solid leaf. It is possible that this practice may refer to the Paraguay tea, so extensively used in South America; but in either case the merit of it is the same. But tea proper is so used among the Lipchas on the slopes of the Himalayas. There, after drinking up the tea-liquor prepared in the ordinary way, the spent leaves themselves are shared by the family and guests, and are highly relished.

The four substances above mentioned are the most important ingredients of the tea-leaf. It contains, besides, some starch and gum, part of which will, of course, be extracted by boiling water, and will give a certain nutritive value to the infusion. Nor should we omit to mention the iron and manganese it contains, both being important elements in the composition of our bodies. The *ashes* of souchong tea have been found to contain 3.29 of peroxide of iron in 100 parts, and 0.71 of oxide of manganese. From an *infusion* of pekoe-leaves weighing 70 grams (a gram is upwards of 15 grains), 0.104 gram of peroxide of iron and 0.20 gram of protoxide of manganese was obtained by Fleitmann. Tea, however, varies in composition with the mode of drying, with the age of the plant and of the leaf, with the season in which it is gathered, and even with the variety of shrub on which it has grown. Hence the proportion of the whole leaf which is extracted by

boiling water varies much both in kind and quantity. The genuine green teas, which are usually prepared from the young leaves, yield more of the lighter-coloured—the black teas more of the darker-coloured ingredients. And even of teas of the same colour and name in the market, different samples yield to boiling water very different proportions of soluble matter. M. Péligot, who tried twenty varieties, found that green teas yield to water from 40 to 48, and black teas from 31 to 41 per cent of their whole weight: later experiments have given similar results.

It is obvious, therefore, that the value of tea as a beverage, in so far as this depends on the proportion of soluble matter it contains, differs very much. We usually judge of the quality of a tea by its aroma, and by the flavour and colour of the infusion it yields; and these, in the main, are good guides: but chemistry indicates that, as in the case of opium, some weight ought also to be attached to the proportion of soluble ingredients it contains and readily yields to boiling water. If 100 grains of the crushed tea will not give up to boiling water at least as much as 26 grains of soluble extractive matter (good teas often yield 36 grains), then the sample is bad. It then consists of, or contains, spent tea already used, redried, and coloured, or else it has been damaged by water. Not long since a cargo of tea, amounting to between 40 and 50 tons, sank in the Thames, and was afterwards recovered. To fit it for sale, it was redried, after receiving various additions.

It is necessary to mention, before concluding my remarks upon tea, that, in addition to the substances which it naturally contains, others are sometimes added by way of adulteration to the teas of commerce. This is especially the case with the green teas, which are not all prepared by simply drying the natural leaf as already described, but are often artificially coloured by the addition of blue, white, and yellow colouring substances. Mr Fortune, who saw the colouring performed in China, thus describes the process: "The superintendent having taken a portion of Prussian blue, threw it into a porcelain bowl not unlike a mortar, and crushed it into a very fine powder. At the same time a quantity of gypsum was burned in the charcoal-fire which was then roasting the tea. This gypsum having been taken out of the fire after a short time, readily crumbled down, and was reduced to powder in

the mortar. The two substances thus prepared were then mixed together, in the proportion of four of gypsum to three of Prussian blue, and formed a light-blue powder, which was then ready for use.

"This colouring matter was applied to the teas during the last process of roasting. About five minutes before the tea was removed from the pans, the superintendent took a small porcelain spoon, and with it he scattered a portion of the colouring matter over the leaves in each pan. The workmen then turned the leaves rapidly round with both hands, in order that the colour might be equally diffused. To 14 lb. of tea about 1 oz. of colouring matter was applied.

"During this part of the operation the hands of the workmen were quite blue. I could not help thinking that if any green-tea drinkers had been present during the operation, their taste would have been corrected and improved.

"One day an English gentleman in Shanghae, being in conversation with some Chinese from the green-tea country, asked them what reasons they had for dyeing the tea, and whether it would not be better without undergoing this process. They acknowledged that tea was much better when prepared without having any such ingredients mixed with it, and that they never drank dyed teas themselves; but remarked that, as foreigners seemed to prefer having a mixture of Prussian blue and gypsum with their tea, to make it look uniform and pretty, and as these ingredients were cheap enough, the Chinese had no objections to supply them, especially as such teas always fetched a higher price!"[1]

Mr Fortune describes the blue substance employed as Prussian blue; and Mr Warington's experiments show that formerly this substance was very generally in use in China for giving an artificial colour to teas. More recently, however, it is said that indigo has been substituted, in consequence, probably, of the injurious effects which European writers have described the Prussian blue as likely to produce on the constitution of green-tea drinkers. The quantity of either substance employed, however, is so minute that, without justifying the adulteration, I think it unlikely that any serious consequences can have followed from it. The indigo is probably harmless; but supposing Prussian blue to be used, the

[1] Fortune's Tea Countries of China, vol. ii. p. 69.

quantity added to the green tea is about one grain to the ounce; and this is already diluted to a pale tint with white clay, so as not to contain more than a third, or probably a fourth, of a grain of pure Prussian blue. This quantity in an ounce of tea is, I think, but little to be dreaded; nevertheless the practice ought to be discouraged and abandoned.[1]

Less doubt exists as to the pernicious qualities of an adulterated tea largely manufactured by the Chinese under the name of Lie tea. This consists of the sweepings and dust of the tea-warehouses cemented together with rice-water and rolled into grains. It is made either black to imitate caper, or green to resemble gunpowder, and is manufactured professedly for the purpose of adulterating the better kinds of tea.

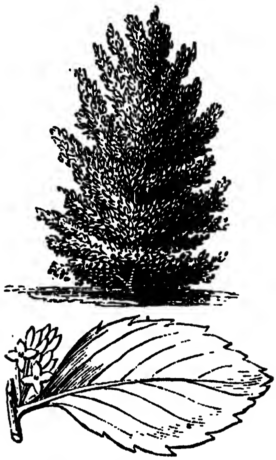
Genuine tea yields only 5 or 6 per cent of ash when burned, being the proportion of mineral matter naturally contained in the leaf; and of this ash rather more than half is soluble in water. The Lie teas sometimes leave as much as 45 per cent of ash, consisting chiefly of sand and other insoluble impurities. These adulterated teas have been imported into this country to the extent of half a million pounds' weight in a single year. In this, as in similar cases, the poorest classes, who can least afford it, are the greatest sufferers from the fraudulent introduction of the spurious mixture into the teas they buy. Among the low dealers the Lie tea is known by the name of *dust and gum*. Mr Midhurst found no less than 53,000 lb. willow-leaves manipulated for tea adulteration at one port alone.

II. Maté, or Paraguay Tea, though not used over so large an area as the Chinese tea, is as much the passion of the Brazilians and their neighbours, in Southern America, as the latter is of the nations of north-eastern Asia. It is prepared from the dried leaves of the Brazilian holly (*Ilex paraguayensis*)—(fig. 23)—is said to have been in use among the In-

[1] It is easy to determine whether indigo or Prussian blue is the colouring matter of these adulterated teas. If a portion of the tea be shaken with cold water and thrown upon a bit of thin muslin, the fine colouring matter will pass through the muslin and settle to the bottom of the water. When the water is poured off, the blue matter may be treated with chlorine or a solution of chloride of lime. If it is bleached, the colouring matter is indigo. If potash makes it brown, and afterwards a few drops of sulphuric acid make it blue again, it is Prussian blue.

dians from time immemorial, has been drunk by all classes in Paraguay since the beginning of the seventeenth century, and is now consumed by "almost the whole population of South America." The leaf of this tree is 4 or 5 inches long, and after being dried it is, in Brazil at least, rubbed to powder before it is infused. The dried leaf has much of the aroma of some varieties of Chinese tea, and the infusion has a pleasant odour, and an agreeable bitter taste. In the state in which it is commonly used in South America, it is more exciting than China tea, producing a kind of intoxication, and by excessive use leading even to *delirium tremens.*

Fig. 23.



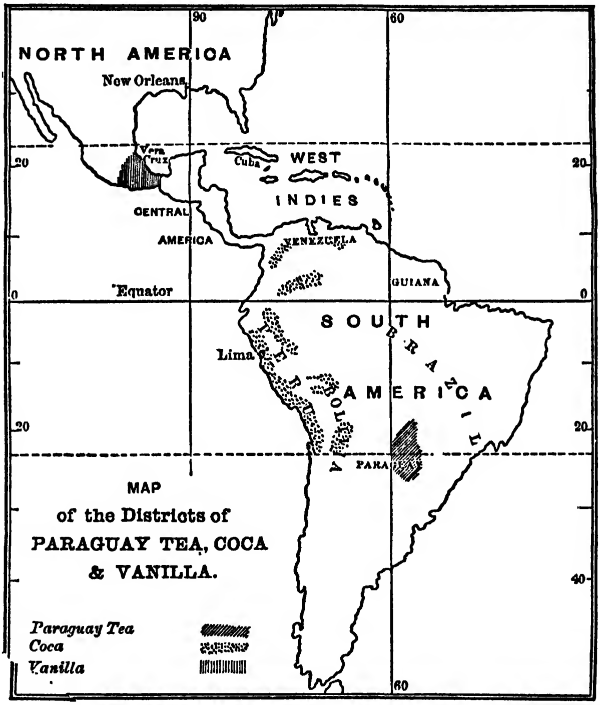
Ilex paraguayensis—Paraguay Holly. (Paraguay Tea-plant.) Scale, 1 inch to 10 feet. Scale for leaf, 1 inch to 4 inches.

The tree which yields the Yerba (the herb or plant *par excellence*), as this tea is called, does not appear to be an object of culture. It grows spontaneously, in extensive natural plantations, amid the forests of Paraguay. The principal Yerbals, or woods of this tree, are situated in the neighbourhood of a small town called Villa-Real, about 1500 miles above Assumption, on the Paraguay river. They are scattered about, however, in various other localities upon the rich tract of country which extends between the rivers Paranà and Uruguay. Permission to gather the leaves is granted by the government to certain merchants, in return for a considerable money payment. These merchants fit out parties of men, chiefly Indians, for the purpose of collecting the Yerba, and at the proper season proceed to the forests. When in the course of their journey they come to a Yerbal, or growth of maté-trees, sufficiently extensive to make it worth their while to halt and collect the leaves, they begin by constructing a long line of wigwams, which they cover with the broad leaves of the banana and palm. Under these they expect to pass nearly six months. An open space is then prepared, of

which the soil is beaten with heavy mallets until it becomes hard and smooth. Over this is erected a kind of arch, made of hurdles, called a *Barbagua*, upon which the Yerba branches are placed. Beneath these a large fire is kept up till the foliage is thoroughly dried and roasted, without being scorched or suffered to ignite. The hard floor is then swept clean, the dried branches are laid upon it, and the now brittle leaves beaten off with sticks, which partly reduce them to powder. They are then crammed and beaten into sacks made of damp hides, which, when sewed up and left to dry, become in a few days as hard as stone. In these sacks, weighing about 200 lb., the maté is well preserved. The labour of collecting the Yerba, in the midst of these tropical forests, is exceedingly severe, and is said to have been very fatal to Indian life. Many of the Creoles and Mestizos even assert that the Paraguayans have exterminated the poor Indians by compelling them to the labour of collecting this plant.

From the smallest shrubs the finest tea is obtained; but from the same kind of leaves different qualities are procured, according to the mode of preparation, and the kind of weather which prevails. Three principal kinds, however, are prepared and sold in South America under the names of caa-cuys, caa-miri, and caa-guaza—the prefix *caa* signifying the leaf itself. The *first* is prepared from the half-expanded buds: it will not keep, and its consumption is entirely confined to Paraguay. The *second*, from the leaf carefully picked and stripped from the nerves before roasting, as was done by the Jesuits. And the *third*, from the entire foliage, roasted as above described, without any preparation. The two latter varieties are not only used largely in the country of Paraguay, but are exported as far as Lima and Quito.—(Hooker.) It loses in virtue and flavour, and its aromatic bitterness diminishes, by exportation and keeping, so that the infusion is drunk in perfection only on the spot where the leaves are gathered and newly dried. The total amount of maté consumed annually in the whole of South America was estimated by Von Bibra in 1855 as 15,000,000 lb.: this figure now probably represents but a third or a fourth of the actual consumption. Though the annual consumption of maté in the Argentine Republic is not less than 13 lb. per head (27,000,000 lb. in all), yet each inhabitant consumes 2 lb. of coffee and ½ lb. of tea as well.

In Brazil, a variety of maté called Gongonha is in use. It is prepared from the leaves of two other species of holly, the *Ilex*[1] *Gongonha* and the *Ilex theezans;* but I do not know to what extent. In Chili also, a tea called Paraguay tea, but



different from the maté, is prepared from the leaves of the *Psoralea glandulosa;* and in Central America, another variety from those of the *Capraria bifolia.*

The use of the maté is very frequent, as well as very universal, in South America. At every meal, and at every hour of the day, it is drunk. It has acquired the name of *Maté,* which is the hot decoction, from that of the vessel or cup in

[1] Not far from Rio Grande, in Brazil, and near the ocean, the Ilex growth begins.

which it is infused, and from which it is drunk. Hot water is poured upon the powdered leaf, then a lump of burned sugar, and sometimes a few drops of lemon-juice are added. The infusion is sucked through a tube, *bombilla*, often made of silver, which is open at one end, and has a perforated bulb or strainer at the other (fig. 24). The cup is passed from hand to hand, the same cup, and often the same tube, serving a whole party. The leaves will bear to be steeped or watered three times, and the infusion is drunk off quickly, as it soon becomes black if allowed to stand. 100 grains of maté yield about 25 grains of soluble matter to boiling water.

Fig. 24.

Maté or cup, and Bombilla or tube.

"Persons who are fond of maté consume about an ounce a-day. In the mining districts it is most universally taken, experience having shown that fermented liquors are there prejudicial to health.[1] The Creoles in South America are passionately fond of the beverage, and never travel without a supply of the leaf, which they infuse before every meal, and sometimes much oftener, never tasting food unless they have first drunk their maté."[2]

Numerous virtues are ascribed to this favourite beverage. It possesses many of the good qualities of our Chinese tea, while, like opium, it is said to calm the restless, and to arouse the torpid. As is the case with opium also, the habit of using it becomes a kind of second nature, so that to give it up, or even to diminish the customary quantity, is almost impossible. On the other hand, long indulgence, or an immoderate consumption of it, is apt to induce diseases similar to those which follow the excessive use of ardent spirits. It differs both from Chinese tea and from opium in acting upon

[1] A maxim of the Jesuits was,—"*En pais caliente, aguardiente ; en pais frio, agua frio,*"—in the warm country, brandy ; in the cold country, water.

[2] Hooker's London Journal of Botany, vol. i. p. 39.

the kidneys and moving the bowels. The chief constituents of the maté-leaf are four:—

First, Like Chinese tea, it contains a volatile oil, which is produced during the roasting of the leaf, gives it a peculiar, agreeable aroma, gradually escapes from it by keeping, and upon which a portion of its narcotic virtue depends. This is shown by the facts already stated, that the tea becomes less valuable when long kept or carried to great distances, and that it is only drunk in perfection near the Yerbal where it is collected and prepared.

Secondly, Dr Stenhouse has shown that this leaf also contains theine, the vegetable principle which we have described as existing in Chinese tea, and as producing remarkable effects upon the system when introduced into the stomach. The proportion is nearly 2 per cent.

Thirdly, Paraguay tea contains about 16 per cent of a peculiar, astringent acid, analogous to tannin or the tannic acid. For this reason the fresh leaves are used in Brazil by the dyers, while the presence of this substance in the infusion causes it to blacken rapidly when exposed to the air, and makes it necessary to drink it off as soon as it is made. Were it poured out into cups, as is done with Chinese tea, the liquid would become black and repulsive before the eyes of the drinker. Hence the reason for the peculiar mode of sucking it through a tube which is practised in South America, and which at first seems so peculiar to Europeans. And,

Lastly, Like the Chinese leaf, it contains also nutritious gluten. Of this substance about 10 per cent is present in the dried maté, of which only a small proportion dissolves when the tea is infused. The benefit of this ingredient, therefore, is experienced only where the infused leaf is subsequently eaten, as is the case, it is said, in some parts of South America.

It is both interesting and remarkable to find, so far, a great similarity between the Chinese and the South American leaf. Both contain the same active ingredients, and both, though belonging to very different tribes of plants, have been selected to serve the same remarkable physiological purposes. How came tribes so remote, and so little civilised, to stumble upon this happy selection?

III. Coffee-Tea.—Attention has been drawn to the use of the leaf of the coffee-tree as a substitute for that of the tea-tree. In 1845 Professor Blume of Leyden, who had travelled much in Java, made known in Holland that this leaf was so used in the Eastern Archipelago, and recommended it for trial in Europe. Subsequently it was made known in this country by Professor Brande; and at the Great Exhibition in 1851, Dr Gardiner showed specimens of prepared coffee-leaves, announcing at the same time that they contained *theine*, and suggesting that they should be substituted for our ordinary tea.

These, along with other circumstances, have drawn the attention of Eastern merchants to the subject; and it appears from various communications which have been made public, that the use of coffee-leaves in this way is an old practice in the Eastern Archipelago. In the Dutch Island of Sumatra especially, prepared coffee-leaves form "the only beverage of the whole population, and, from their nutritive qualities, have become an important necessary of life."

The leaves are roasted over a clear, smokeless bamboo-fire, till they become of a brownish-buff colour. They are then separated from the twigs, the bark of which, after a second roasting, is rubbed off and used along with the leaves. In this state they have an extremely fragrant odour, resembling that of a mixture of tea and coffee. When immersed in boiling water, they give a clear brown infusion, which, with sugar and cream, forms an agreeable beverage. Mr Ward, many years settled at Pedang, in Sumatra, thus narrates his experience in regard to the use of the coffee-leaf in that island:—

"The natives have a prejudice against the use of water as a beverage, asserting that it does not quench thirst, or afford the strength and support the coffee-leaf does. With a little boiled rice and infusion of the coffee-leaf, a man will support the labours of the field in rice-planting for days and weeks successively, up to the knees in mud, under a burning sun or drenching rain, which he could not do by the use of simple water, or by the aid of spirituous or fermented liquors. I have had the opportunity of observing for twenty years the comparative use of the coffee-leaf in one class of natives, and of spirituous liquors in another—the native Sumatrans using

the former, and the natives of British India, settled here, the latter; and I find that, while the former expose themselves with impunity to every degree of heat, cold, and wet, the latter can endure neither wet nor cold for even a short period, without danger to their health.

"Engaged myself in agriculture, and being in consequence much exposed to the weather, I was induced several years ago, from an occasional use of the coffee-leaf, to adopt it as a daily beverage, and my constant practice has been to take two cups of a strong infusion, with milk, in the evening, as a restorative after the business of the day. I find from it immediate relief from hunger and fatigue. The bodily strength is increased, and the mind left for the evening clear and in full possession of its faculties. On its first use, and when the leaf has not been sufficiently roasted, it is said to produce *vigilance;* but I am inclined to think that, where this is the case, it is rather by adding strength and activity to the mental faculties, than by inducing nervous excitement. I do not recollect this effect on myself except once, and that was when the leaf was insufficiently roasted.

"As a beverage the natives universally prefer the leaf to the berry, giving as a reason that it contains more of the bitter principle, and is more nutritious. In the lowlands, coffee is not planted for the berry, not being sufficiently productive; but, for the leaf, the people plant it round their houses for their own use. It is an undoubted fact that everywhere they prefer the leaf to the berry." [1]

He adds further, that while the culture of the coffee-plant, for its fruit, is limited to particular soils and more elevated climates, *it may be grown for the leaf wherever, within the tropics, the soil is sufficiently fertile.* This is a very important fact, and, should the leaf come into general use, will no doubt lead to the introduction of new forms of husbandry in many tropical regions, from which the coffee-tree, as a profitable article of culture, has been hitherto excluded. At present the price of the prepared leaves in Sumatra is about 1½d. a-pound; and they may be packed of good quality, for the European market, for 2d. a-pound.

In regard to the constituents of the dried coffee-leaf, the agreeable aroma emitted shows that, like Chinese tea, it con-

[1] Pharmaceutical Journal, vol. xiii. p. 208.

tains a volatile oil, which will probably act upon the system like the similar oils of tea and coffee. It has been proved also to contain theine to the extent of about $1\frac{1}{2}$ per cent—(STENHOUSE)—and an astringent acid closely resembling that which is found in Paraguay tea. Both of these are present in it in larger proportion than in the coffee-bean; and hence, probably, the reason why the leaf is preferred to the bean by the natives of Sumatra. These, with about 13 per cent of gluten and some gum, are all the important ingredients yet found in the leaf. But the presence of these substances proves it to be so similar to the tea-leaf in composition, as to lead to the belief that it may be successfully substituted in common use for the Chinese tea. And this conclusion is supported by the wakefulness which is said to be produced by the infusion of coffee-leaves, by the bodily refreshment it is found to yield, by the directly nutritive power which the leaves possess, and by the general favour they have found in the estimation of the people of Sumatra.

To boiling water the dried coffee-leaves yield about 39 per cent of their weight—as much as is taken up by water from the most soluble varieties of the coffee-bean, and more than is yielded by average Chinese tea. In this property, therefore, the leaf of the coffee-tree is also equal to the bean.

IV. KOLA is the name used in Angola for the fruit of a tree closely allied to the Baobab. In Congo it is called Makasso; and Guru in Soudan. It is introduced here because the seeds are not only used in West and Central Africa for preparing a beverage, but because they have recently been found to contain theine. The kola-tree is *Sterculia acuminata,* and perhaps *S. kola* also. Five seeds or so, like peeled chestnuts, are found in each pod. They have an acrid and bitter flavour. A bit of kola is often eaten with green ginger in the morning by natives at Loanda.—(MONTEIRO.)

V. LABRADOR TEA is the name given in North America to the dried leaves of the *Ledum palustre* and the *Ledum latifolium* (fig. 25). These plants grow on the borders of the swamps, and along the heathy shores of the mountain lakes in the colder regions of that continent. The leaves are gathered and used in the stead of Chinese tea—the narrower-leaved

plant (*L. palustre*), according to Dr Richardson, giving tea of the better quality. Both varieties are very astringent, and possess a narcotic, soothing, and exhilarating quality. This narcotic quality is so strong, that in the north of Europe (Sweden and Germany) these plants are secretly employed by fraudulent brewers to give headiness to beer. They have not as yet been examined chemically. From the above facts, however, we may infer that, besides a variety of tannin, to which they owe their astringency, they contain an active narcotic principle, more powerful, probably, than the theine of the tea-leaf, to which their peculiar, exhilarating, and stupefying effects are due. It is possible also that, in the cold northern climates of Sweden and Labrador, the effects of such a narcotic substance may be less sensibly felt than under our milder skies.

Fig. 25.

Ledum palustre—The Marsh Ledum, or Labrador Tea. The undermost flower and leaf represent those of *Ledum latifolium*—The Labrador Tea, or broad-leaved Ledum.

Scale, 1 inch to 2 feet. Leaves and flowers nearly natural size.

VI. Abyssinian Tea, called in its native country Kât or Kaat, is very extensively cultivated in Shoa and the adjoining regions, and is in general use among the inhabitants, just as tea is in China. It consists of the dried leaves of the *Catha edulis*, a species of small tree which is allied to the *Sageretia theezans*, from which the poorer classes of Chinese prepare an inferior kind of tea. In a light gravelly soil the plant attains a height of 12 feet. The leaves are plucked in the dry season, and well dried in the sun. In Abyssinia they sell at 1d. or 2d. a-pound.[1] They are either chewed, boiled in milk, or infused in boiling water, and, by the addition of honey, yield a pleasant beverage. They have much resemblance to Chinese tea, both in their qualities and their effects. They are bitter to the taste, possess exhilarating properties, and dispel sleep if used to excess.

1 Harris—Highlands of Ethiopia, vol. ii. p. 423.

The leaves of this plant are also used green. Forskäll states that the Arabs eat them green because of their property of preventing sleep. To such a degree do they exhibit this influence, that a man who chews them may stand sentry all night without feeling drowsiness. They are also regarded as an antidote to the plague; and the Arabs believe that the plague cannot appear in places where the tree is cultivated. Botta adds to these qualities that, when fresh, the leaves are very intoxicating.[1]

This North African tea appears to be very extensively cultivated and used, though less so now than in ancient times; but we have no means of estimating the absolute quantity which is grown and consumed. We are entirely ignorant also, I believe, of its exact chemical history, and do not yet know whether it belongs to the class of plants in which theine exists. Its relation to the *Sageretia theezans* of China renders this not unlikely.

VII. Other Teas.—Many other plants, of which the chemistry has been but imperfectly studied or remains unknown, are used in various countries as more or less perfect substitutes for Chinese tea. Thus, the name

Tasmanian Tea is given to the dried leaves of various species of Melaleuca and Leptospermum, belonging to the order of the Myrtaceæ, which are collected in Australia, and used by the colonists instead of Chinese tea. These trees are commonly called tea-trees, and the large tracts of country which are covered with them, *tea-tree flats*. The leaves of various species of Correa also, which belong to the Rutaceæ, and especially of the *Correa alba*, are collected and used for the same purpose. The leaves of *Acæna sanguisorba*, a plant allied to the Rosaceæ, and which abounds everywhere in Tasmania, are said to be an excellent substitute for tea. Even the bark of the Australian sassafras (*Atherosperma moschata*) has obtained some celebrity as a tea-substitute. In the same eastern region the leaves of the *Glaphyria nitida*, another of the Myrtaceæ—called by the Malays the Tree of Long Life—affords at Bencoolen, in Sumatra, a substitute for tea.

Faham Tea, again, is the name given in Mauritius to the dried leaves of the *Angræcum fragrans*—a fragrant orchid.

[1] Lindley—Vegetable Kingdom, p. 587.

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The plant is a parasite, like the misletoe, and is allied to the well-known vanilla, of the odour of which it reminds us. It grows on trees in the Isle of Bourbon. The Africans have long employed its leaves as medicine, and the infusion of its leaves as a drink. The infusion of these leaves is exceedingly pleasant to the smell, and in taste holds the medium between vanilla and bitter almonds. Its fragrance is owing to the presence of *coumarin*, the odoriferous principle of the Tonka-bean, and of mellilot, described in a subsequent chapter.[1] This leaf does not contain theine, and is not therefore to be classed in its virtues and uses with the Chinese and Paraguay teas.

Besides all these we have North American substitutes for the China leaf, distinguished by the names of Appalachian tea, Oswego tea, Mountain tea, and New Jersey tea. We have a Mexican tea, a Brazilian tea,—the aromatic *Capitaô da matto*,—a Santa Fé tea, an Indian (Toolsie) tea, and many others. Of the chemistry of most of these substitutes we know little. I have, however, embodied in the following table some few facts regarding them:—

[1] See "The Odours we Enjoy."

[TABLE.

SUBSTITUTES FOR CHINESE TEA AND MATÉ.

Name of Plant.	Natural order.	Where collected and used.	Popular Name.
Catha edulis, C. spinosa,	Celastraceæ.	Arabia. Abyssinia.	Arabian tea. Kaat or kât.
Sageretia theezans,	Rhamnaceæ.	China.	?
Ceanothus americanus,	Do.	N. America.	New Jersey tea.
Psoralea glandulosa,	Leguminosæ.	Chili.	?
Cyclopia vogelii,	Do.	Cape.	Boer tea.
Prunus spinosa ⅓, Fragraria collina, or F. vesca, ⅔,	Drupaceæ. Rosaceæ.	N. Europe.	Sloe and strawberry tea.
Glaphyria nitida (flowers)	Myrtaceæ.	Bencoolen.	Long-life tea.
Leptospermum scoparium, and L. thea,	Do.	New Holland.	Tea-plants. Tasmanian tea.
Melaleuca genistifolia and M. scoparia,	Do.	Do.	
Myrtus ugni,	Do.	Chili.	?
Helichrysum serpyllifolium,	Compositæ.	Cape.	Colony tea.
Gaultheria procumbens,	Ericaceæ.	N. America.	Mountain tea.
Ledum palustre, L. latifolium,	Do.	Do.	Labrador tea. James's tea.
Ocymum album,	Labiatæ.	India.	Toolsie tea.
Monarda didyma, M. purpurea,	Do.	N. America.	Oswego tea.
Micromeria theasinensis,	Do.	France.	?
Salvia officinalis,	Do.	N. Europe.	Sage tea.
Hydrangea thunbergii,	Lythraceæ.	Japan.	Ama tsja: tea of heaven.
Acæna sanguisorba,	Sanguisorbiaceæ.	New Holland.	"Burr" of colonists.
Styrax alstonia,	Styracaceæ.	New Granada.	Santa Fé tea.
Capraria bifolia,	Scrophulariaceæ.	Central America.	?
Correa alba,	Rutaceæ.	New Holland.	Cape Barran tea.
Lantana pseudothea,	Verbenaceæ.	Brazil.	Capitaô da matto.
Stachytarpheta jamaicensis,	Do.	Austria.	Brazilian tea.
Chenopodium ambrosioides,	Chenopodiaceæ.	Mexico and Columbia.	Mexican tea.
Viburnum cassinoides, Prinos glaber,	Caprifoliaceæ. Aquifoliaceæ.	N. America. Do.	Appalachian tea.
Angræcum fragrans,	Orchidaceæ.	Mauritius.	Bourbon or Faham tea.

I pass over numerous other plants which in Europe have been tried as substitutes for tea, without, however, coming into any general use, except here and there as adulterations. It is possible that some of those above mentioned may hereafter be discovered to contain the theine and other valuable constituents of the true tea-leaf, and may be both cultivated and advantageously used in its stead. As an adulteration, the leaves of *Epilobium angustifolium*—Rosebay willow-herb—are sometimes mixed with tea to the amount of 25 per cent. From South America the leaves of *Stachytarpheta mutabilis* have been imported for the same purpose.

CHAPTER VIII.

THE BEVERAGES WE INFUSE.

THE COFFEES.

Coffee used in Abyssinia from time immemorial.—Its introduction into Europe.—Consumption in the United Kingdom, in Europe, and in the whole world.—Varieties of coffee: Liberian coffee.—Effects of the infusion of coffee.—It exalts the nervous life, and lessens the waste of the system.—Constituents of coffee.—The volatile oil; its production, mercantile value, and effects on the system.—The tannic acid, the theine or caffeine, and the gluten.—Composition of tea and coffee compared.—Loss of weight in roasting coffee.—Proportion of the roasted bean taken up by water very variable.—Substitutes for coffee.—Seeds of the water-iris, of the Turkish kenguel, of the roasted acorn, of roasted corn and pulse, of roasted roots, and especially of chicory.—The chicory plant and root.—How the root is prepared for use.—Gives a fictitious appearance of strength to coffee.—Active ingredients in chicory. The empyreumatic oil, and the bitter principle.—Its effects on the system.—Mode of detecting chicory in coffee.—Adulterations of chicory.

In antique days a poor dervish, who lived in a valley of Arabia Felix, observed a strange hilarity in his goats on their return home every evening. To find out the cause of this he watched them during the day, and observed that they eagerly devoured the blossoms and fruit of a tree which hitherto he had disregarded. He tried the effect of this food upon himself, and was thrown into such a state of exaltation that his neighbours accused him of having drunk of the forbidden wine. But he revealed to them his discovery, and they at once agreed that Allah had sent the coffee-plant to the faithful as a substitute for the vine.

The name of Coffee is given to a beverage prepared from the seeds of plants roasted, ground, and infused in boiling water. The seeds of the Arabian coffee-tree are the most largely used for this purpose, but various other seeds are more or less extensively employed in a similar way.

I. ARABIAN COFFEE.—The tree which produces this seed is said to be indigenous to the countries of Enárea and Cáffa, in southern Abyssinia. In these districts the coffee-tree grows like a wild weed over the rocky surface of the country. It is grown and used in Angola. The roasted seed or bean has also been in use as a beverage in Abyssinia generally from time immemorial, and is at the present day extensively cultivated in that country. In Persia it is known to have been in use as early as the year 875. From Abyssinia it was introduced into Arabia at least as early as the beginning of the fifteenth century, when it partly superseded the older kaat or Abyssinian tea. About the middle of the sixteenth century it began to be used in Constantinople, and, in spite of the violent opposition of the priests, became an article of general consumption. In the middle of the seventeenth century (1652), the first coffee-house was opened in George Yard, Lombard Street, London, by a Greek named Pasqua; and twenty years after, the first was established in Marseilles. Since that time both the culture and consumption of coffee have continually extended. It has become the staple produce of important colonies, and the daily and most cherished drink of probably more than a hundred millions of men.

The consumption in the United Kingdom in 1852 amounted to 35 millions of pounds, of which upwards of 20 millions were brought from Ceylon, 4 millions from Jamaica, and 8 millions from Costa Rica and Brazil. In 1857 the total imports were 58,912,629 lb., while the amount entered for home consumption was 34,518,555 lb. In 1867 the total imports were 137,729,716 lb.; in 1876 they had risen to 152,501,664 lb. On the continent of Europe it is much more generally used than among ourselves. The total European consumption was estimated a few years ago at 75,000 tons, or 168 millions of pounds, valued at 4½ millions sterling. It probably now exceeds 360 millions of pounds. The entire weight of coffee now raised over the whole world is believed to exceed half a million of tons.

The quality of raw coffee does not appear to depend so much on the mode of collecting and drying it as that of tea does. Soil and climate are the circumstances which chiefly affect its commercial value. The flavour and quality of the beverage prepared from it depend very much, however, upon the manner of roasting the bean, and of subsequently preparing the infusion. This infusion, as commonly made in this country, is such utter rubbish, that there is no difficulty in accounting for the disfavour with which coffee is now often regarded here. In fact the consumption per head of the population of the United Kingdom has actually decreased. Taking the average consumption of three years, in each period we find the following figures:—

Mean of the 3 years . .	1857, '58, '59.	1865, '66, '67.	1875, '76, '77.
Lb. consumed per head, .	1¼	1	¾

The consumption of coffee per head in 12 European states is about:—

	lb.		lb.
Holland, ...	21	France, ...	2¾
Denmark, ...	14	Austro-Hungary, . .	2
Belgium, ...	13½	Greece, ...	1⅓
Norway, ...	9¾	Italy, ...	1
Switzerland, ...	7	United Kingdom, . .	0¾
Sweden, ...	6	European Russia, . .	0¼

The consumption in the United States is believed to amount to 8 lb. per head.

The Arabian or Mocha coffee is small, and of a dark-yellow colour. The Javan and East Indian are larger, and of a paler yellow. Very little true Mocha or Yemen coffee reaches those parts of Europe which are west of Constantinople. The Ceylon, West Indian, and Brazilian have a bluish or greenish-grey tint.[1] The Liberian coffee is the produce of *Coffea liberica*, and is a fine, large, well-flavoured seed. This African species of coffee has been successfully introduced into several of our colonies and dependencies, and appears to be more robust and prolific than the common sort, which it is likely in part to supplant.

The coffee-tree (fig. 26), when in good health and full grown, attains a height in some countries not exceeding 8 or 10, but in others averaging from 15 to 20 feet. Von Bibra says it sometimes reaches a height of 40 feet; but in the

[1] For a map of the countries which produce coffee and sugar, see Chapter X.—"The Sweets we Extract"—p. 200.

Brazils he found the average height to be from 12 to 15 feet. It is covered with a dark, smooth, shining, and evergreen foliage. It is sown in nurseries—transplanted when about six months old—begins to flower at two years, and in three years comes into full bearing, and in favourable circumstances will continue to bear for twenty years. And it does this in all seasons, so that throughout the year its white blossoms delight the eye, and its red fruit enriches the owner. It flourishes in a dry soil and a warm situation, but not too warm: and hence in hot climates it grows best at an elevation of 1000 or 1500 feet above the level of the sea. Coffee grows from the equator to 36° north latitude, in damp and shady situations, in free soils, and in a mean temperature of 20° C. Its range is nearly the same as the cotton-plant. It gives three crops a-year. Its flowers are pale white, fragrant, and rapidly fading; its fruit is like that of the cherry-tree, but it grows in clusters. Within the fruit are the seeds or "berries." On dry and elevated spots the berries are smaller, and have a better flavour; but berries of all sizes improve in flavour or *ripen* by keeping. The small berries of Arabia will ripen in three years, but the worst coffee produced in America will, in from ten to fourteen years, become "as good, and acquire as high a flavour, as the best we now have from Turkey."—(Ellis.)

Fig. 26.

Coffea arabica—Arabian Coffee-tree.
Scale, 1 inch to 10 feet.
Scale for leaf, 1 inch to 2 inches.

The sensible properties and effects of coffee, like those of tea, are too well known to require to be stated in detail. It exhilarates, arouses, and keeps awake; it counteracts the stupor occasioned by fatigue, by disease, or by opium; it allays hunger to a certain extent, gives to the weary increased strength and vigour, and imparts a feeling of comfort and repose. Its physiological effects upon the system, so far as they have been investigated, appear to be that, while it makes the brain more active, it soothes the body generally, makes the change and waste of matter slower, and the demand for food in consequence less. All these effects it owes to the conjoined action of three ingredients, very similar to those contained in tea. These are, a volatile oil produced during the roasting—a variety of tannic acid, which is altered during the roasting—and the substance called theine or caffeine, which is common to both tea and coffee.

1st, *The Volatile Oil.*—When the coffee-bean is gathered and dried in the air it has little smell, and only a slightly bitter and astringent taste. As with the tea-leaf, it is during the roasting of coffee that the much-prized aroma and the greater part of the taste and flavour are brought out or produced. In tea, as we have seen, the proportion of volatile oil amounts to about half a pound in a hundred of the dried leaf, but in roasted coffee it rarely amounts to more than one in fifty thousand! And yet on the different proportions of this oil which they severally contain, the aroma and the consequent estimation in the market of the different varieties of coffee in a great measure depend. A higher aroma would make the inferior Ceylon, Jamaica, and East Indian coffees nearly equal in value to the finest Mocha; and if the oil could be bought for the purpose of imparting this flavour, it would be worth in the market as much as £100 sterling an ounce!—(Payen.) How it comes—by what slow chemical change within the bean, that is—that coffee of the most inferior quality so ripens by keeping as at length to yield, on roasting, a coffee equal to the finest Mocha, we do not as yet know. The oil is formed during the roasting by the action of the heat on some substance present in the natural bean, probably in small quantity only. It is possible that by prolonged keeping this substance is itself produced in the inferior qualities of coffee; so that, when roasted after the

keeping, a larger quantity of the valuable aromatic oil is formed in the bean.

The effect of this volatile oil of coffee upon the system has been made the subject of direct experiment. When roasted coffee is distilled with water this oil passes over, and by drinking the distilled water and oil together its effects may be ascertained. Julius Lehmann found in this way that it has an effect in retarding the waste of the tissues quite equal to that of caffeine itself. It produces also an agreeable excitement and a gentle perspiration, dispels the sensation of hunger, and moves the bowels. In its exhilarating action upon the brain it is said by Moleschott to affect the imagination less than the reasoning powers.

These effects followed when the quantity of oil yielded by two ounces of coffee was taken in a day. If this dose was doubled, violent perspiration came on, with sleeplessness and symptoms of congestion.

It appears, therefore, that the volatile empyreumatic oily constituents of roasted coffee, though present only in minute quantity, exercise a powerful influence upon the animal economy, exciting to greater activity both the vascular and nervous systems, and yet retarding the waste of the tissues in as great a degree as the caffeine itself, which the infusion of coffee usually contains. This activity of the volatile oil of coffee justifies us in concluding, as I have already said, that the similar oil produced in tea by the roasting, takes a similar share in the effects which the infusion of tea as a beverage produces.

2dly, *The Astringent Acid.*—The raw coffee contains about 45 per cent of an astringent acid—the caffeic or caffeotannic—which does not blacken a solution of iron, as the infusion of tea does, but renders it green,[1] and does not precipitate solutions of gelatine. This acid is changed to some extent during the roasting, but still retains a portion of its astringent properties, and contributes in some degree to the effects which the infusion of coffee produces upon the system.

[1] Many varieties of the astringent, so-called tannic acids are found in plants; that which exists in tea has much resemblance to the tannin of the oak—while those of coffee, of Paraguay tea, and of the heaths (Ericaceæ), form a class of acids which have much resemblance to one another, but differ in their properties from the tannic acid of the oak.

It will be observed that the proportion of this astringent principle contained in coffee is much less than is contained in tea. Hence it is not sufficient to retard the action of the bowels as tea does, especially when associated with the empyreumatic volatile oil, which, as we have seen, has a positive tendency to move them. To the same result the large percentage of fat contained in coffee may also contribute.

3dly, *The Theine*, or *Caffeine* as it is also called, exists in different proportions in different varieties of coffee. It varies in the coffee usually employed in this country from three quarters of a pound to one pound in the hundred—(STENHOUSE); though, according to some experimenters, three or four pounds in the hundred occur in certain varieties of coffee. By rubbing common roasted coffee in a mortar with a fifth of its weight of slaked lime, and then boiling the mixture in alcohol, about half a per-cent of theine may be readily extracted. Weight for weight, therefore, tea yields about twice as much theine as roasted coffee does to the water in which it is infused. But as we generally use a greater weight of coffee than we do of tea in preparing our beverages, a cup of coffee of ordinary strength will probably contain as much theine as a cup of ordinary English tea. A cup of strong French coffee will contain twice as much caffeine as a cup of weak French tea.

The influence which this ingredient of the several beverages has in producing the effects we experience from the use of them, has already been explained when treating of the effects of tea.

But the coffee-bean contains also about thirteen per cent of nutritious gluten, which, as in the case of tea, is very sparingly dissolved by boiling water, and is usually thrown away in the insoluble dregs of the coffee. Among some of the Eastern nations, the custom prevails of drinking the *grounds* along with the infusion of the coffee: in these cases the full benefit is obtained from all the positively nutritive matter which the roasted coffee contains. What that nutritive matter is will be seen in the following estimate, made by Payen. (The *litre* is about a pint and three quarters of our measure.)

	Total solid substances.	Nitrogenous substance.		Fats, sugar, and salts.
"½ litre of infused coffee, .	9.5 grams.	4.53 grams.		4.97 grams.
½ litre of milk, . .	70 "	45 "		25 "
Average amount of sugar,	75 "	...		75 "
Total,	154.5 "	49.53 "	+	104·97 "

This liquid thus represents six times as much solid substance, and three times as much nitrogenous substance, as the same quantity of *bouillon*. We must therefore admit that coffee possesses nutritive properties, but its principal value is its aroma and taste."

The composition of roasted coffee, compared with the average composition of the tea-leaf as it comes to Europe, is nearly as follows:—

	Tea.	Coffee.
Water, ...	8	5
Theine, ...	2½	¾
Tannin, ...	14	4
Essential oil, ...	½	*trace*
Minor extractives, ...	15	36
Insoluble organic matter, ...	54½	50
Ash, ...	5½	4¼
	100	100

The proportion of theine in both tea and coffee, it will be recollected, is somewhat variable. Another important difference between tea and coffee is the absence of iron and manganese from the latter. If the ashes of the two be examined, that of tea will be found to contain both iron and manganese; while that of coffee contains only a trace of iron, and not even a trace of manganese.

Coffee swells by roasting, but loses in weight, and assumes a brown colour more or less dark. These changes vary, however, with the degree of roasting. Thus—

Roasted to a	It loses in weight	And gains in bulk
Reddish brown, .	15 per cent.	30 per cent.
Chestnut brown, .	20 per cent.	50 per cent.
Dark brown, . .	25 per cent.	50 per cent.

The aroma is most agreeable when the heat is not greater than is sufficient to impart a light-brown colour to the bean. When the roasting is carried too far, a disagreeable smell gradually mingles with the esteemed aroma, and lessens the value of the product.

The quantity of the coffee-bean which is taken up by water is nearly the same before and after roasting. It is nearly the same also in some samples, whether they be much or little roasted. It varies, however, very much in different samples.

Some infusions of coffee, even when roasted to the same extent, contain three times as much of the solid substance of the coffee as others do. But we have no experiments upon the comparative effects which infusions so differing have upon the constitution of the drinkers. On an average, it is reckoned, in Paris, that boiling water will dissolve 25 per cent of reddish-brown, and 19 of chestnut-brown coffee. It is observed, however, that some natural waters give a stronger and better-flavoured coffee than others; and this has been traced, as in the waters of Prague, to the presence of alkaline matter in those which give the most agreeable infusion. Hence, to obtain a more uniformly strong and well-flavoured coffee, it is recommended to add a little soda to the water in which the infusion is made. About forty grains of dry carbonate of soda, or twice as much of crystallised, are sufficient for a pound of coffee.

The chemical changes caused by the roasting, are the production of the active empyreumatic oil, and of a brown bitter substance, the chemical properties of which, and its action upon the system, still remain to be investigated. They are produced from the soluble part of the raw bean, but by what chemical changes is not yet known.

In conclusion, it is proper to state that coffee is reputed to possess important medicinal virtues. The great use of coffee in France is supposed to have abated the prevalence of gravel in that country. In the French colonies, where coffee is more used than in the English, as well as in Turkey, where it is the principal beverage, not only gravel, but gout, is scarcely known. Among others, also, a case is mentioned of a gentleman who was attacked with gout at twenty-five years of age, and had it severely till he was upwards of fifty,

with chalk-stones in the joints of his hands and feet; but the use of coffee then recommended to him completely removed the complaint.[1]

It has not been determined to which of the constituents of coffee this curative action is due, or whether it is the same in all constitutions. These points are worthy of careful experimental investigation. The Arabs, Von Bibra tells us, even to this day roast the fruit, and not simply the bean; this they call *sakka* or *salabi—café à la sultane.* They seldom use the bean. The inhabitants of Yemen and Hedjaz use the inner shell of the fruit, which they prefer to the seeds; but they make a cordial of the decoction, adding cloves, cinnamon, and aromatic spices and gums. In Brazil, raw sugar and unroasted coffee-berries are stirred together and roasted in a covered pan into a mass. A bit of this is taken, pounded in a mortar, and put into a linen bag. Boiling water is poured through it, and the cups to be filled placed beneath.

II. Other Coffees.—Several varieties of the *Coffea arabica*, or coffee-plant, are grown in various countries, and yield a useful marketable bean. Distinct names have been assigned to the coffee-plants of Silhet and Nepaul, of the coast of Mozambique, of the coast of Zanzibar, and of the Mauritius. The seed of the last of these tastes disagreeably sharp and bitter, and sometimes causes vomiting, yet it is in some places cultivated instead of the *Coffea arabica.* It is probable that these plants are differently modified forms of the same original species. The Liberian coffee is said to be distinct.

But, besides the fruit of the different true coffee-plants, numerous other vegetables have, in different countries, been proposed or used as substitutes for Arabian coffee. A successful substitute must contain, like coffee, a fragrant aromatic principle, a bitter principle, and an astringent principle. These properties are found more or less satisfactorily—

a. In the roasted seeds of *Iris pseudacorus* (yellow water-iris), which are said to approach very near to coffee in quality.

b. In the seeds of a *Goumelia*, called in Turkey *Kenguel*, which were shown at the Great Exhibition of 1851 as extensively cultivated in the Kair-ar-eh and Komah, where they are roasted, ground, and used as coffee.

[1] Pharmaceutical Journal, vol. xiii. p. 330.

c. In the roasted acorn, which is much used on the Continent under the name of acorn coffee, and is now imported into and prepared in England for the use of the adulterator.

d. In the roasted cicer or chick-pea; in beans, rye, and other grains; in nuts, almonds, and even in wheaten bread, when roasted carefully; and in date-stones.

e. In the seeds of Broom (*Spartium scoparium*), and in the dried and roasted berries of *Triosteum perfoliatum* (Caprifoliaceæ). In the West Indies, the seeds of several species of *Psychotria* (Cinchonaceæ); in Soudan, those of Dura and Nitta (*Inga biglobosa*); among the African negroes, those of *Parkia africana;* and among the Tonguses, those of a species of *Hyoscyamus,*—are all employed as substitutes for coffee. In South Africa, the seeds of *Brabejum stellatum,* the wild Amandel, belonging to the Myristicaceæ, are roasted and used as coffee.

f. In the dried and roasted roots also of many plants. The carrot and turnip are used for this purpose in Germany, and the roots of the common goose-grass (*Galium Aparine*) in Ireland; while those of the dandelion (*Leontodon Taraxacum*) and of chicory are extensively employed both in this country and on the Continent. In none of these roots, however, has the characteristic principle, theine, been discovered, and none of them, therefore, can serve the same physiological purposes as the seeds of our common coffee.

Yet one of these roots (chicory) has already crept into extensive use in other countries, and among ourselves is held in some estimation. At first it was only mixed with pure coffee as an adulteration by fraudulent dealers. But this practice extended itself so widely, that, for the defence both of the honest dealer and of the public, the sale has been legalised, and much chicory in the unmixed state is now bought and used instead of or along with genuine coffee. As one of the recognised beverages we *now* infuse, therefore, the plant deserves a brief notice in this place.

III. Succory, chicory, or wild endive (*Cichorium Intybus*) fig. 27, is one of our native weeds, which, with its large pale-blue flowers, is seen scattered about in numerous places. It has a large white parsnip-like tap-root, which increases in size when the plant is subjected to cultivation. This root

abounds in a bitter juice, which has led to its use as a substitute for coffee. The plant is now extensively cultivated for the sake of its root. In England the culture is chiefly confined to the counties of Surrey, Bedford, and York. On the Continent it is largely grown in Germany, Belgium, in the province of Hainault, Brabant, the two Flanders, and Antwerp, and in France. In Holland it is grown in Friesland, and used in that province and in Groningen. Much is grown in Magdeburg, where several thousand acres are devoted to its culture; hence 20 to 30 millions of pounds of roasted chicory-roots are yearly exported. The foreign is considered greatly superior to that of English growth, and is extensively imported into this country, chiefly through Hamburg and Antwerp.

Fig. 27.

Cichorium Intybus—The Chicory-plant.
Scale, half-inch to a foot.

The root is taken up before the plant shoots into flower, is washed, sliced, and dried; it is then roasted till it is of a chocolate colour. Two pounds of lard are roasted with each hundredweight, and the dried root loses in roasting from 25 to 30 per cent. When ground and exposed to the air, it becomes moist and clammy, increases in weight, and acquires a distinct smell of liquorice, and a sensibly sweet *first* taste. It possesses in no degree the pleasant aroma which recommends the genuine roasted coffee. When infused, even in cold water, it imparts to it a dark colour, and a sweetish-bitter taste. To many the addition of a little of this bitter liquid to the infusion of genuine coffee appears an improvement—a remarkable illustration of the creation of a corrupt taste by an adulteration, which taste demands afterwards the continuance of the adulteration to satisfy its own craving. The bitter substance itself, however, is not considered unwholesome. Very many bitter substances of this kind possess a tonic property, and it is not unlikely that the bitter principle of chicory may be among the number.

But the use of chicory appears to have originated from other causes than the discovery, or even the supposed presence, of a tonic property in its bitter ingredient. A little of the roasted chicory gives as dark a colour to water, and as bitter a taste, as a great deal of coffee, and hence it was originally introduced into the coffee-houses for a purpose akin to that which takes chiretta-root and quassia-chips into the premises of the brewer. It gave colour and taste to the beverage of the drinker, and at the same time saved the expensive coffee of the seller. The public taste gradually accommodated itself to the fraudulent mixture; it became by-and-by even grateful to the accustomed palate, and finally a kind of favourite necessity to the lovers of *dark-coloured bitter coffee.* It has even injured the beverage we now obtain from genuine coffee, by introducing the practice of roasting it darker, and thus lessening both its nutritive quality and its aroma. How far circumstances are gradually giving to the infusion of chicory, in some countries, the character of a national beverage, may be judged of from the facts, that in 1845 the quantity of chicory imported into this country was estimated at 2000 tons, or 4½ millions of pounds, and it had increased to 5800 tons in 1876; that the quantity of the roasted root consumed in France amounts already to 30 millions of pounds a-year; and in Belgium, with its small population of 4½ millions, to 20 millions of pounds; while in some parts of Germany the women are becoming regular chicory-topers,[1] and are making of it an important part of their ordinary sustenance. But there is some excuse for the deluded people that like chicory, and esteem it as equal to coffee. Coffee must be roasted fresh, ground fresh, and brewed quickly into an aromatic, perfectly clear liquor, or it is unworthy of its true repute and name. The drink that passes for coffee, and is *genuine* enough, it may be, is often not worth drinking.

The active ingredients in roasted chicory are, *first,* the empyreumatic volatile oil: this is produced during the roasting; and though not so fragrant, this oil probably exercises upon the system some of the gently-exciting, nerve-soothing, and hunger-staying, influence of the similar ingredients contained in tea and coffee: and, *secondly,* the bitter principle.

[1] "Cichorien-Kaffee-Schwelgerinnen."—Strumpf, Die Fortschritte der Angewandten Chemie.

When taken unmixed, this substance is to many, while they are unaccustomed to it, not only disagreeable, but nauseous in a high degree. It may, however, like many other bitter principles, possess, as I have said, a tonic or strengthening property. Taken in moderate quantities, these ingredients of chicory are probably not injurious to health; but by prolonged and frequent use they produce heartburn, cramp in the stomach, loss of appetite, acidity in the mouth, constipation with intermittent diarrhœa, weakness of the limbs, trembling, sleeplessness, a drunken cloudiness of the senses, &c. &c. At the best, therefore, chicory is a substitute for coffee to which only those to whom the price is an object ought to have recourse.

The simplest way of detecting an admixture of chicory in coffee, is to put the powder in cold water. Chicory gives a coloured infusion in the cold while coffee does not, and by the depth of the colour the proportion of chicory may be guessed at. But by more minute chemical and microscopical analysis it is possible to ascertain the amount of the adulteration.

The infusion or decoction of a suspected mixture may be tested also by salts of peroxide of iron. The infusion of chicory is brownish yellow, and becomes only a little darker when such a salt of iron is added, giving no precipitate. The infusion of coffee is of a brown colour, becomes green when the iron solution is added, and gives a brownish-green precipitate.

Another reason why the use of chicory should be avoided by those who can afford to buy pure coffee, is found in the fact, that pure chicory is as difficult to be met with in the market as unadulterated coffee. The common ground chicory of Berlin has been found to contain half its weight of roasted turnips. On the Rhine, the carrot is used along with other roots instead of the turnip. Venetian red, also, is very commonly employed to impart to the chicory a true coffee colour; and it is curious to observe how the practice of adulteration extends itself from trade to trade. The coffee-dealer adulterates his coffee with chicory to increase his profits; the chicory-maker adulterates his chicory with Venetian red, to please the eye of the coffee-dealers; and, lastly, the Venetian-red manufacturer grinds up his colour with brick-dust, that by his greater cheapness, and the variety of shades he offers, he

may secure the patronage of the traders in chicory! In Holland, a species of coffee-syrup is mixed with the coffee to darken the colour. It is prepared by boiling down molasses, with apples, pears, and other fruits, in an iron pot. The cold "toffy" is broken into bits, and kept enclosed in tin canisters: about one ounce is used with half a pound of coffee. The chicory of France is largely adulterated. Seventy-five samples bought in Parisian shops showed sixty-four adulterated, mainly with earthy matters, as sand, earth, refuse bone-black, and sifted ashes, but also with roasted bread, acorns, and other vegetable products.

CHAPTER IX.

THE BEVERAGES WE INFUSE.

THE COCOAS.

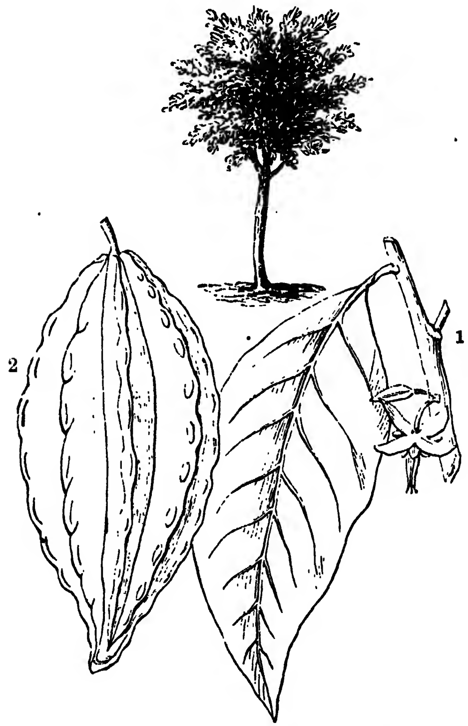
Cocoa, ancient use of, in Mexico.—Brought to Europe by the Spaniards.—The tree and its fruit.—Varieties in the market.—Quantity imported into this country.—Manufacture of the bean.—Cocoa-nibs.—Cocoa of commerce.—Chocolate.—Constituents of cocoa.—The volatile oil.—The peculiar bitter principle, theobromine.—The large proportion of fat which characterises cocoa.—The starch and gluten.—Its general composition compared with that of milk.—It forms a most nutritious beverage.—Substitutes for cocoa. The earth-nut and the guarana of Brazil.—Decoction of cocoa-nibs not so nutritious.—The cocoa-husk or "miserable;" importation of, and beverage made from.—General view of the chemistry of the infused beverages.—Summary of their physiological action.—Concluding reflections.—Prison dietaries.

The Cocoas, as I have said, are more properly soups or gruels than simple infusions. They are prepared from certain oily seeds, which are first ground to a pulp by passing them between hot rollers, and are then diffused through boiling water for immediate use.

I. The Mexican Cocoa is the seed of the *Theobroma cacao* (fig. 28), a small but beautiful tree with bright dark-green leaves, which occurs both wild and cultivated in the northern parts of South America, and also in Central America as far north as Mexico. If left to itself, it attains a height of 40 feet, but Von Bibra says that cultivators never let it grow beyond 15 or 20—partly to facilitate the gathering of the fruit, and partly to shield it from the influence of high winds. It

is grown chiefly in Brazil, Guiana, Trinidad, and on the coast of Carácas, and forms whole forests in Demerara. It is cultivated also in the Mauritius, and in the French island of

Fig. 28.



Theobroma cacao—The Cacao, "Cocoa," or Chocolate tree. Scale, 1 inch to 10 feet.

1, Leaf and flower; 2, Fruit or pod. Scale, 1 inch to 2 inches.

Bourbon. When the Spaniards first established themselves in Mexico, they found a beverage prepared from this seed in common use among the native inhabitants. It was known by the Mexican name of Chocollatl, and was said to have been in use from time immemorial. It was brought thence to

Europe by the Spaniards in 1520, and has since been introduced more or less extensively as a beverage into every civilised country. Linnæus was so fond of it that he gave to the tree the generic name of Theobroma—Food of the Gods.

The fruit of the tree, which, like the fig, grows directly from the stem and principal branches, is of the form and size of a small oblong melon or thick cucumber (2, fig. 28). It contains 50 or more beans or seeds, imbedded in rows in a spongy substance, like that of the water-melon. When ripe, the fruit is plucked, opened, and allowed to ferment slightly. The seeds are cleaned from the marrowy substance, and dried in the sun. In the West Indies they are often immediately picked for market; but in the Carácas they are gathered into heaps every evening and covered over, or sometimes buried in the earth till they undergo a slight fermentation, before they are finally dried and picked for market. By this treatment they lose a portion of their natural bitterness and acrimony of taste, which is greater in the beans of the mainland than in those of the American islands. The cocoa of Central America is, however, of superior quality, or at least is more generally esteemed in the European market than that which is grown in the West Indies. It still retains a greater degree of bitterness, and this may be one reason for the preference given to it.

In the low country of Tabusco the cocoa-tree bears flowers and fruit all the year round, but seldom more than ten fruits on a single tree at one time. The principal harvests are in March, April, and October, and the total yield of the province is 200 tons.

In 1867 nearly 12 millions of pounds of cocoa were imported into Great Britain: it had risen to 20½ millions in 1876. Since June 1853 the duty on cocoa-seeds has been 1d. per lb.

The total production of cocoa has been estimated at 100 to 110 millions of pounds, 28 millions of which are raised in Ecuador, 11 in Trinidad, and 7 in Brazil.

The consumption of cocoa in the United Kingdom has nearly tripled during the last decade; it approaches 5 ounces per head annually. Just 10 millions of pounds were retained for home consumption in 1876.

The cocoa-bean of commerce is brittle, of a dark-brown

colour internally, eats like a rich nut, and has a slightly astringent but distinctly bitter taste. This bitterness is more decided in the South American or mainland varieties. In preparing it for use, it is gently roasted in an iron cylinder, in the same way as coffee is roasted, till the aroma appears to be fully developed, when it is allowed to cool. The bean is now more brittle, lighter brown in colour, and both the natural astringency and the bitterness are less perceptible than before. It is manufactured for the market in one or other of three principal ways. *First,* The whole bean after roasting is beaten into a paste in a hot mortar, or is ground between hot rollers adjusted for the purpose. This paste, mixed with starch, sugar, and other similar ingredients in various proportions, forms the granulated, flake, rock, and soluble cocoas of the shops. These are often gritty from the admixture of earthy and other matters which adhere to the husk of the beans. *Secondly,* The bean is deprived of its husk, which forms about 11 per cent of its weight, and is then crushed into fragments. These form the cocoa-nibs of the shops, and are the purest state in which cocoa can usually be obtained from the retail dealer. *Thirdly,* The bean, when shelled, is ground at once into a paste by means of hot rollers, and is then mixed with sugar, and seasoned with vanilla and bitter almonds, sometimes with cinnamon and cloves. This paste forms the long-known chocolate.

When prepared, it is also used in three different ways. *First,* The chocolate is made up into sweet cakes and bonbons, and is eaten in the solid state as a nutritious article of diet, containing in a small compass much strength-sustaining capability. *Secondly,* The chocolate or cocoa is scraped into powder, and mixed with boiling water or boiling milk, when it makes a beverage, somewhat thick, but agreeable to the palate, refreshing to the spirits, and highly nutritious. *Thirdly,* The nibs are boiled in water, with which they form a reddish-brown decoction, which, after the fat has been skimmed off, is poured from the insoluble part of the bean. With sugar and milk this forms an agreeable drink, better adapted for persons of weak digestion than the consumption of the entire bean. Another variety of the cocoa beverages, one which may be called cocoa-tea, is prepared by boiling the husks of the bean in water, with which they form a brown

decoction. This husk is usually ground up with the ordinary cocoas, but it is always separated in the manufacture of the purer chocolates. Hence in the chocolate manufactories it accumulates in large quantities, which are imported into this country from Trieste and other Italian ports, under the name of "miserable." This has been used for cattle-feeding. Here the husk is partly ground up in the inferior cocoas, so that the ordinary "flake cocoas" are really of three qualities:—

a. Bean and husk ground and flaked together: this quality is worth 120s. per cwt.

b. The contents of the second vessel from the winnowing-fan, consisting of the smaller pieces of the nib, and a good deal of the husk: this sells at 84s. per cwt.

c. The contents of the third vessel from the winnowing-fan, consisting of little else but the husk, and selling at 56s. per cwt. Unfortunately *b* is often sold as *a*, and *c* as *b*.

Besides the exhilarating and sustaining properties which it possesses in common with tea and coffee, cocoa, in its more common forms, is eminently nutritious. Its active or useful ingredients are the following:—

First, The volatile oil, to which its aroma is due, and which is produced during the roasting. The proportion of this oil in the roasted bean has not been determined, but it is no doubt very small. Its action on the system is probably similar to that of the odoriferous oils produced by the same process in tea and coffee.

Secondly, A peculiar principle, resembling the theine of tea and coffee, though not identical with it. Like theine, it is a white crystalline substance, which has a slightly bitter taste, and contains a large percentage of nitrogen. It is called by chemists *theobromine,* from the generic name of the cocoa-tree; and its composition, compared with that of theine, is as follows:

	Theine.	Theobromine
Carbon, ...	49.5	46.7
Hydrogen, ...	5.1	4.4
Nitrogen, ...	28.9	31.1
Oxygen, ...	16.5	17.8
	100.0	100.0

It is richer in nitrogen, therefore, even than theine; and as nearly all vegetable principles, rich in nitrogen, of which the influence upon the system has been examined, are found

to be very active, the same is inferred in regard to theobromine. And further, Strecker has shown that caffeine may be made from theobromine by a process called "methylation," in which one atom of carbon and two of hydrogen are added to the original substance. Its analogy in chemical properties to theine leads to the belief that it exercises a similar exhilarating and soothing, hunger-stilling and waste-retarding effect to the latter substance. The benefits experienced from the use of cocoa are due, in part at least, therefore, to the theobromine it contains. The proportion of this substance in the cocoa-bean has been estimated at from 1½ to 2 per cent—the same proportion in which theine exists in the tea-leaf. It exists, also, in sensible quantity in the husk of the bean. The decoction obtained by boiling the husk in water, cannot, therefore, be wholly devoid of useful ingredients, or of good effect.

Thirdly, The predominating ingredient in cocoa, and the one by which it is most remarkably distinguished from tea and coffee, however, is the large proportion of fatty matter, known as cocoa-butter, which it contains. This sometimes amounts to upwards of one-half the weight of the shelled or husked bean. Consumed in either of its more usual forms, therefore, cocoa is a very rich article of food, and for this reason it not unfrequently disagrees with delicate stomachs. It is in some measure to lessen the sense of this richness or heaviness, that sugar, starch, and fragrant seasonings are so generally ground up with the roasted bean in the manufacture of cocoa and chocolate.

Fourthly, It contains also a large proportion both of starch and gluten,—substances which, as we have elsewhere seen, form the staple constituents of all our more valuable varieties of vegetable food.

The average composition of the entire bean, when deprived of its husk, and gently roasted ready for use, is nearly as follows:

Water,	5
Starch, gum, tannin, colouring matter,	28
Gluten, &c.,	11
Oil (cocoa-butter),	48
Theobromine,	2
Fibre,	3
Ash or mineral matter,	3
	100

This composition reminds us of the richest and most nutritive forms of vegetable food; and especially of the oily seeds and nuts with which cattle are fed and fattened.

It is rich in all the important nutritious principles which are found to coexist in our most valued forms of ordinary food, but is somewhat poor in gluten or nitrogenous flesh-formers, though excessively rich in heat-givers, especially in fat. When mixed with water, however, as it is usually drunk, it is more properly compared with milk than with infusions of little direct nutritive value, like those of tea and coffee. And, on the other hand, it has an advantage for some purposes over milk, over beef-tea, and other similar beverages, in that it contains the substance theobromine and the volatile empyreumatic oil. Thus it unites in itself the exhilarating properties of tea with the strengthening and ordinary body-supporting qualities of milk.

As cocoa is rich in fat, and milk in casein, the practice of making milk-cocoa, in which the constituents of the one ingredient dovetail into and assuage the influence of those of the other, is a judicious one. The large proportion of oil it contains justifies also, as fitting it better for most stomachs, the practice of mixing or grinding up the cocoa with sugar, flour, or starch, in the preparation of cocoa-paste, or chocolate. Both practices are indeed skilful adjustments, made without chemical knowledge, as the results of long and wide experience. But excellent powder-cocoas are now prepared in which the cheaper starch has not been introduced, but merely some of the excess of butter pressed out. For it must not be forgotten that no cocoas are really soluble, though often so called. Such cocoas mixed with boiling water form starch-paste in which the particles of cocoa remain suspended. And, lastly, the general composition of the beans shows that, in chocolate cakes and comfits, when faithfully prepared, there should reside, as experience has also shown to be the case, much nutritive virtue, and the means, reduced into comparatively small compass, both of supporting the bodily strength and of sustaining the nervous energy.

II. Brazilian Cocoa, or Guarana.—In Brazil the seeds of the *Paullinia sorbilis* are collected, dried in the sun, or gently roasted, and used in the same way as those of the *Theobroma*

cacao. The most usual native preparation of guarana is of ground seeds made into a paste with water and rolled into a sausage-like shape. These rolls are heavy and very hard, and are known as Guarana bread. When used, these cakes are mixed with water, in the same way as we employ the cakes of cocoa or chocolate, and the mixture is sweetened and drunk. This article is prepared and consumed very largely by the lower classes in Brazil, especially in the provinces of Para and Amazonas. It is a fact of great interest in regard to this substance, and one which shows it to have a true place among the beverages of which we are now treating, that, like tea and coffee, it has been found to contain theine, and that to the extent of 5 per cent, and it is therefore capable of exercising upon the system an influence similar to that which is experienced by those who use these two favourite beverages. It has been introduced into Europe as a remedy in sick-headache. But it occasionally purges violently, owing in all probability to the presence of an irritant substance called *saponin.*

III. Other Cocoas.—The substances, as yet known, which can be employed in the place of, or as substitutes for Mexican cocoa, are comparatively few in number. To fit them for this purpose they must contain an odoriferous principle of some degree of fragrance, abundance of fat, and a considerable amount of ordinary nutriment. Oily seeds and nuts are almost the only vegetable productions from which beverages resembling cocoa have anywhere been manufactured. Among these the ground-nut (*Arachis hypogæa*), a kind of oily pea, the pod of which forces itself into the ground and there ripens, is roasted in South Carolina, Angola, and elsewhere, and then prepared and used in the same way as chocolate. In Spain the root of the *Cyperus esculentus*, or earth-chestnut, is roasted and used as a substitute for both coffee and chocolate, but especially for the latter, which is much consumed in Spain.

These are all the professed substitutes for the cocoa-bean with which I am acquainted. Neither of the two last mentioned, however, contains a bitter principle, rich in nitrogen, of the nature of the theobromine of the true cocoa, or of the theine contained in guarana. They can never, therefore, be employed effectively to replace the Mexican cocoa.

As adulterating materials, the substances chiefly employed by fraudulent manufacturers of cocoa and chocolate are the husks of the cocoa-bean, starch, sugar, fat, ground roots, and red ochre. The admixture of starch and sugar which our prepared cocoas and chocolates contain is at least not an unsalutary adulteration, although it is profitable to the manufacturer. The same cannot be said, however, of the red ochre with which cocoa-beans have been found to be artificially coloured. The presence of the ochre is detected by burning the cocoa in the air. If the ash is grey, the cocoa is pure; if red, it is adulterated with ochre. But it would seem that this colouring with a red ochreous earth is done in some cocoa countries merely to improve the colour, even the best beans being subjected to this treatment.

Before I leave this subject, it may interest the reader if I briefly sum up what appears to be the actual state of our knowledge regarding the chemistry and physiology of the beverages we infuse.

First, As to the chemistry of the various leaves and seeds we have mentioned, it appears that, when roasted and ready for use, they all contain—

a. A volatile, odoriferous, aromatic oil, which does not exist in the fresh leaf or seed, but is produced or developed during the roasting. In coffee this oil is most abundant, in tea probably next, and in cocoa least in quantity. In the teas (Chinese and Paraguay), and in roasted coffee, the quantity and activity of this oil appear to diminish by keeping. In raw coffee, on the other hand, the power of developing this oil by roasting becomes greater when the raw bean is kept or allowed to ripen.

b. A peculiar, bitter, crystallisable principle, containing much nitrogen, and exerting a specific action on the system. In the teas, in coffee, and in guarana, this principle is theine, which contains 29 per cent of nitrogen; in cocoa, it is theobromine, which contains 31 per cent of nitrogen. Weight for weight, the average qualities of tea contain about twice as much theine as the average qualities of coffee—2 per cent in the former to 1 per cent in the latter—but in both it varies between 1 and 4 per cent as extremes. In cocoa the proportion of theobromine is about 1½ to 2 per cent. In well-roasted coffee, and in chicory, another bitter principle, which

is soluble, uncrystallisable, and free from nitrogen, is produced during the roasting.

c. A variety of tannin or tannic acid, which gives their astringency to the infusions prepared from all these substances. Of this ingredient the teas contain most, coffee next, and cocoa the least. The tannin of Chinese tea gives a black, that of maté and of coffee a green colour, with solutions containing iron.

d. A nutritious substance resembling the gluten of wheat or the fibrin of beef. In the tea-leaf this ingredient is most abundant, in coffee next, while cocoa contains the least. It dissolves but sparingly in water, and is therefore generally lost to the consumer when only the infusion is drunk. The full benefit of this ingredient is obtained only when the tea-leaves are eaten, when the coffee-grounds are taken along with the infusion, or when the whole material is made into a beverage, as in the usual modes of preparing cocoa and chocolate. But in the case of coffee and tea, especially the latter, this nutritive nitrogenous matter does not exist in a very available or digestible condition.

e. A quantity of fat, which in cocoa forms half the whole weight of the bean, in coffee one-eighth or less, and in tea only 1 or 2 per cent. The presence of so large a proportion of fat gives a peculiar character to cocoa, rendering it most nutritious, especially when made with milk, to those whose stomachs will bear it, but making it less suitable at the same time to persons of weak digestive powers.

Of the infusions themselves which are yielded by the different varieties of tea, maté, and coffee, it is to be observed that they vary in strength with the sample employed. Of some teas and coffees, boiling water will extract and dissolve as much as one-third of the whole substance; of others, not more than one-sixth. The proportions of the several ingredients above mentioned, which the infusions we prepare are likely to contain, must therefore be variable.

Secondly, As to the physiology of these beverages, or their action on the system, it appears—

a. Generally, that they all exert a remarkable influence on the activity of the brain—exalting, so to speak, the nervous life; and yet they do so in a way different from opium or ardent spirits, since they act as antidotes to the narcotic in-

fluence of the one, and relieve the intoxication produced by the other.

(b) They all soothe the vascular or corporeal system, allay hunger, retard the change of matter, and diminish the amount of bodily waste in a given time; and if this waste must, in the healthy body, be constantly restored in the form of ordinary food, this diminution of the waste is equivalent to a lessening of the amount of food which is necessary to sustain the body—hence their value to the poor. They are *indirectly* nutritious.

(c) Specially, they diminish the quantity of carbonic acid given off from the lungs in a given time—(PROUT); and that also of urea and phosphoric acid in the urine—(JULIUS LEHMANN). These are the chemical forms in which the lessening of the change of matter manifests itself. In the case of coffee, it has been ascertained by experiment that this lessening of the waste is due more to the empyreumatic oil than to the caffeine. The same is probably true also of tea.

(d) The increased action of the heart, the trembling, the headache, and the peculiar intoxication and delirium which extreme indulgence in coffee sometimes produces, are mostly caused by the caffeine. On the other hand, the increased action of the kidneys, of the bowels, and of the perspiring vessels, and generally the increased activity of the whole system, are ascribed to the action of the oil. That Chinese tea has an astringent or costive effect upon the bowels, may arise from the larger proportion of the astringent tannic acid which tea contains being able to counteract the effect of the oil. That there is a specific difference in the action of the empyreumatic oils of tea and maté, compared with that of coffee, is further probable from the remarkably intoxicating effect which both the Chinese and the Paraguay leaves possess when newly gathered and roasted for use.

Of course the general effect of these beverages upon the system is the combined result of the simultaneous action of all their constituent ingredients. But possessing the two characteristic influences of retarding the change of matter and of increasing at the same time the activity of the nervous life, they cannot, according to our present knowledge, be replaced by the strongest soups or flesh-teas, or by any other infusions or decoctions which merely supply the ordinary kinds of nourishment in more or less diluted and digestible forms.

In some countries it is the custom to heighten the natural flavour of roasted coffee by the addition of spices. Thus M. de Saulcy, in his tour round the Dead Sea, found the Bedouins in the country of ancient Moab drinking coffee, of which he says that it was "an absolute decoction of cloves."[1] On the continent of Europe, and in North and South America, vanilla is said to be employed largely for flavouring coffee as well as chocolate. In Germany it is used also, as well as rum, to give taste and flavour to weak infusions of tea. To the other more natural influences of coffee and tea these spices add a stimulating effect, which appears to expend itself chiefly upon the animal propensities.

A perusal of the history of these beverages leaves lingering in our minds some interesting general facts, which are suggestive of many thoughts.

The first is, the vast extent to which the materials for these beverages are cultivated and used, and the important place they occupy among what may be called the artificial necessities of life. Our data for forming correct calculations as to the quantity of each beverage which is grown and consumed are very defective, but we may guess them at about—

Chinese tea, ...	2350	millions of	pounds.
Maté, ...	60	,,	,,
Coffee, ...	1150	,,	,,
Chicory, ...	120	,,	,,
Cocoa, ...	110	,,	,,

—forming an aggregate of upwards of 3700 millions of pounds of the raw materials consumed annually in the preparation of the beverages we infuse.

Nor is the number of people to whom these warm beverages have become necessaries of life less surprising. Thus—

	Is consumed in	By about		
Chinese tea,	China, Russia, Tartary, England, Holland, North America, and Australia,	500	millions of	men.
Maté or Paraguay tea,	Peru, Paraguay, Brazil, &c.,	10	,,	,,
Coffee-tea, .	Sumatra, &c.,	2	,,	,,
Coffee-bean, .	Arabia, Ceylon, Jamaica, Germany, France, North America,	110	,,	,,
Chicory, . .	Germany, Belgium, France, England,	50	,,	,,
Cocoa, . .	Spain, Italy, France, Central America, Mexico,	60	,,	,,

[1] Journey Round the Dead Sea, vol. i. p. 313.

So that upon these five plants about half of the whole human race are dependent for one of their most useful and most harmless forms of indulgence.

A second point which strikes us in the history of these beverages—at least of the teas and coffees—is, that they have come more and more into use in Europe and America as the intellectual activity which distinguishes the leading nations of modern times has developed itself. The kind of ordinary food upon which the consumers of these beverages usually live no doubt modifies the influence they exercise upon the system. It is even probable that the nature of this food is one of the causes which determine the preference given to tea or to coffee by the different European nations. And, reasoning from this probability, we might say that there is too much of mere vulgar nutrition in cocoa to allow it to influence the nervous or intellectual life to an equal degree with tea and coffee; and in this we possibly might find a reason for the less prominent intellectual position which has been occupied by Spain and Italy since cocoa has become an article of such universal consumption in these countries.

A third striking fact is, that the poorest and humblest amongst us, who has his own little earnings to spend, devotes a small part of them to the purchase of tea or coffee. He can barely buy bread and milk, or potatoes and salt, yet the cup of tea or coffee is preferred to the extra potato or the somewhat larger loaf. And if thereby his stomach is less filled, his hunger is equally stayed, and his comfort, both bodily and mental, wonderfully increased. He will probably live as long under the one regimen as the other; and while he does live, he will both be less miserable in mind, and will show more blood and spirit in the face of difficulties, than if he had denied himself his trifling indulgence. Besides the mere brickwork and marble, so to speak, by which the human body is built up and sustained, there are rarer forms of matter, as these chapters have shown, upon which the life of the body and the comfort of animal existence most essentially depend. This truth is not unworthy the consideration of those to whom the arrangement of the dietaries of our prisons and other public institutions has been intrusted. So many ounces of gluten, and so many of starch and fat, are assigned by these food-providers as an ample allowance for everyday use. From these dietaries, except for the infirm and the invalid, tea and

coffee are for the most part excluded.[1] And in this they follow the counsel of those who have hitherto been regarded as chief authorities on the chemistry of nutrition. But it is worthy of trial whether the lessening of the general bodily waste which would follow the consumption of a daily allowance of coffee would not cause a saving of gluten and starch equal to the cost of the coffee;—and should this not prove the case, whether the increased comfort and happiness of the inmates, and the greater consequent facility of management, would not make up for the difference, if any. The inquiry is an interesting one in physiological economics, and it is not undeserving of the serious attention of those benevolent minds which, in so many parts of our Islands, have found in the prisons and houses of correction their most favourite fields of exertion.

I might add, as a stimulus to such experiments, the evident craving for some such indulgence as a kind of natural necessity, which is manifested in the almost universal practice among every people not absolutely savage, of preparing and drinking beverages of this sort. If there be in the human constitution this innocent craving, it cannot be misplaced humanity to minister to it, even in the case of the depraved and convicted. Where reformation is aimed at, the moral sense will be found most accessible where the mind is maintained in most healthy activity, and where the general comfort of the whole system is most effectually promoted.

[1] See the Author's Elements of Agricultural Chemistry and Geology, sixth edition, p. 394.

CHAPTER X.

THE SWEETS WE EXTRACT.

THE GRAPE AND CANE SUGARS.

Mineral sweets.—Vegetable sweets.—Number of these known to modern nations.—The grape-sugars; their sensible and chemical characters.—Honey-sugars.—Trebizond honey.—Poisoning of Xenophon's soldiers.—Fruit-sugars.—Starch or potato sugar, manufacture of.—Sugar from rags, from sawdust, and from Carraigeen, Ceylon, and Iceland mosses.—The cane-sugars.—Spread of the sugar-cane from Asia through Europe to America. —Varieties of the sugar-cane.—Nutritive qualities of the raw cane-juice.—Extensive consumption of it.—Composition of the sugar-cane.—Manufacture of cane-sugar.—Difficulties in the manufacture.—Great loss of sugar in consequence.—Improvements in the manufacture, and their effects on West Indian prosperity.—Total produce of cane-sugar in the world.—Consumption of sugar in the United Kingdom.—Sensible and chemical characters of cane-sugar.—Beet or European sugar.—Its importance on the continent of Europe.—Number and produce of the manufactories of France and Russia.—Composition of the sugar-beet.—Difficulties in extracting the sugar.—Progress of the manufacture.—Its chemico-agricultural relations.—Palm or date sugars.—Quantity produced yearly.—Maple or North American sugar.—Quantity produced in Canada, New England, and New York.—Mode of extraction.—Chemical changes in the maple-sap.—Maize or Mexican sugar; manufacture of, in the United States, and in France.—Sorghum-sugar, the cane of the north.—Total quantity of sugar extracted for use.—Chemistry in its economical and social relations.

In common life, the sweets we extract are a constant accompaniment of the beverages we infuse. At least, as we use them in Europe and America, sugar is a usual addition to the infusions of tea, coffee, and cocoa.

Of substances which are sweet to the taste, the chemist is familiar with many which have no relation to the wants or

usages of common life. Sugar of lead is a well-known poison, which derives its name from the sweetness of its taste. Silver in certain of its compounds (as the hyposulphite) is equally sweet. A mineral earth called glucina (from γλυκυς, sweet) produces many compounds which have a sugary taste when first put into the mouth; and numerous other instances might be named. It is only those sweet substances, however, which exist in or are extracted from plants, that are directly connected with our modern comforts. These sweets not only accompany, on our tables, the beverages we infuse, but are the ingredients from which our brewers and distillers manufacture the liquors we ferment. They fall naturally to be considered, therefore, in this place.

Of these vegetable sweets, modern nations use many varieties. In such substances, as luxuries of life, we are, indeed, far richer than any of the ancient nations. It is with sugar as with alcohol and common salt. Men knew fermented liquors, and the condiment of sea-water, long before they knew how to separate alcohol from the former, and salt from the latter; in like manner they knew honey and sweet juices of plants before they knew how to separate sugar from the cane. Not until the fifteenth century was the process of sugar-making suspected, and not till long afterwards was it perfected. Thus, to the honey, grape, manna, and fruit sugars, which were the principal sweets of the ancient world, we now add the cane, maple, beet, maize, and palm sugars. We manufacture sugar also from potatoes, rice, and other substances rich in starch; from lichens gathered from the rocks, from sea-weeds thrown upon the shore; even from sawdust, from waste-paper and old rope; and we extract it from the milk of our domestic cattle. It has become to us, in consequence, almost a necessary of life. We consume it in millions of hundredweights; we employ thousands of ships in transporting it. Millions of men spend their lives in cultivating the plants from which it is extracted, and the fiscal duties imposed upon it add largely to the revenue of nearly every established government. It may be said, therefore, to exercise a more direct and extended influence, not only over the social comfort, but over the social condition of mankind, than any other production of the vegetable kingdom, with the exception, perhaps, of cotton alone.

The numerous varieties of useful sugars with which we are acquainted, may be arranged under four main kinds or heads. These are the grape-sugars, found chiefly in fruits; the cane-sugars, chiefly found in stems; the manna-sugars, chiefly found in leaves; and milk or animal sugar. I shall treat of each in its order.

I. The GRAPE-SUGARS include two varieties, of which in various proportions, the sugar of the grape, the sugars of honey, the sugar of fruits, and potato, starch, and paper sugars, are made up.

1°. *Grape-Sugar.*—When the ripe grape is dried in the air, it forms the well-known raisin of commerce. When this raisin is opened, numerous whitish crystalline brittle granules are seen within it, which are sweet to the taste. These consist of what is called grape-sugar, and they are the main source of the sweetness both of the grape, and the raisin, and the currant. This grape-sugar dissolves readily in water, and if yeast be added to the solution, soon enters into fermentation. The results of this fermentation are, first, a spirituous liquor resembling weak wine; and afterwards, as the fermentation proceeds, an acid liquor, like sour wine or vinegar.

In Syria, a sweet preparation is made from the juice of the grape. It consists chiefly of grape-sugar, and is exported to Egypt under the name of *dips* or *dibs*.[1]

2°. *Honey-Sugars.*—The bee has been long known and admired for its industry, and the honey it collects indulged in as a luxury. This honey is formed, or naturally deposited, in the nectaries of flowers, and is extracted from them by the working bees. They deposit it in their crop or honey-bag, which is an expansion of the gullet (œsophagus), and from this receptacle they disgorge it again when they return to the hive. In the interval, it is altered by admixture with the liquids which are secreted in the mouth and crop of the insect—so that the honey we extract from the hive is not exactly in the same chemical condition as when it was sucked up from the flowers by the laborious bee. It no longer contains cane-sugar.

[1] In Genesis xliii. 11, this word is translated *honey*, though the sweet of the grape is probably meant. *Dibs* is also the word used for Samson's honey (Judges xiv. 8), though *Assal* is the word now employed in Syria and Egypt to denote the honey of the bee.

When liquid honey is allowed to stand for a length of time, it gradually thickens and consolidates. By stirring it up with spirits of wine it may then be separated into a white solid sugar, consisting of minute crystals, which remain undissolved, and a thick uncrystallisable syrup, or even glassy mass, which may be got out of the spirituous solution by evaporating it at a gentle heat. Both the crystalline and the vitreous sugars have the same general properties. They are equally sweet; both have the same chemical composition, and both begin to ferment when water and a little yeast are added to them. The crystalline sugar of honey is identical with that of the grape. It is called *dextrose* by chemists, for it deflects a ray of polarised light passed through its solution to the *right*. The vitreous sugar is called *lævulose*, because it is "left-handed." On analysis a good sample of honey yields in 100 parts:—

Water,	22.0
Crystalline glucose (dextrose),	38.0
Vitreous glucose (lævulose),	36.0
Mineral matters,	0.2
Wax, pollen, gluten, essential oil, colouring matters,	3.8
	100

To the two last-named substances honey owes the varied colours, flavours, and fragrances, which in different countries and districts it is known to possess, and for which it is often highly prized. Hence the estimation in which the honey of Mount Ida, in Crete, has been always held. Hence also the perfume of the Narbonne honey, of the honey of Chamouny, and of our own high moorland honey when the heather is in bloom. Sometimes these foreign substances possess narcotic or other dangerous qualities, as is the case with the Trebizond honey, which causes headache, vomiting, and even a kind of intoxication in those who eat it. This quality it derives from the flowers of a species of rhododendron (*Azalea pontica*), from which the honey is partly extracted.[1] It was probably this kind of honey which poisoned

[1] In the valleys of Eastern Nepaul, at a height of 5000 or 6000 feet, Dr Hooker found huge pendulous nests formed by wild bees, the honey of which is much sought for, except in spring, when it is said to be poisoned by rhododendron-flowers, exactly like the honey eaten by Xenophon's soldiers.*

* Himalaya Journals, vol. i. p. 201.

the soldiers of Xenophon, as described by him in the retreat of the Ten Thousand.[1]

Meat may be preserved in honey or syrup: while sugar in some form is frequently added to the salt used in pickling bacon, pork, and other meats. A very curious use of honey was noticed by Hooker. The Khasias, a Himalayan tribe, preserve the bodies of those who die during the rains, when cremation is difficult, in honey, and so await a drier and hotter season.

3°. *Fruit-Sugars.*—Many of our fruits pass, in the course of ripening, from a sour to a sweet state. The apple, the pear, the plum, the peach, the gooseberry, the currant, the cherry, &c., are of this kind. Most of them, even when fully ripe, are still a little acid; the mixture of sweet and sour in their juices adding to their agreeable and refreshing qualities. All such fruits, as a general rule, contain, and owe their sweetness to, grape-sugar. From many of them this sugar can be readily extracted for use; but, in general, it is more economical and agreeable to employ it in the form of dried and preserved fruits, or to make wine of it, as we do of that which exists in the grape, the gooseberry, the apple, and the pear.

4°. *Potato, Starch, and Paper Sugars.*—It is a property of starch of all kinds to be insoluble in cold water, but to dissolve readily in boiling water, and to thicken into a jelly or paste as it cools. Even a lengthened boiling in water, however, produces little further change upon it. But if a small quantity of sulphuric acid (oil of vitriol) be added to the water in which it is boiled, the solution gradually acquires a sweet

[1] The effects of this honey upon his soldiers are thus described by Xenophon: "And there was there (in a village near Trebizond) a number of beehives; and as many of the soldiers as ate of the honeycombs became senseless, and were seized with vomiting and diarrhœa; and not one of them could stand erect. Those who had swallowed but little, looked very like drunk men; those who ate much were like madmen; and some lay as if they were dying. And thus they lay in such numbers, as on a field of battle after a defeat. And the consternation was great. Yet no one was found to have died; all recovered their senses about the same hour on the following day. And on the third or fourth day thereafter, they rose up as if they had suffered from the drinking of poison.—Xenophon, Anabasis, book iv. chap. 8, Τα δε σμηνη, &c.

Auguste St Hilaire, while travelling in the Brazils, experienced symptoms of poisoning after having eaten of honey extracted by a native bee from a plant belonging to the poisonous family of *Apocynaceæ*, or dogbanes.

taste, and ultimately the whole of the starch is converted into grape or honey sugar. A pound of acid diluted with a hundred pounds of water, and employed in this way, will convert into sugar a great many pounds of potato, wheat, rice, or sago starch. If the acid be then separated by lime, and the liquor boiled down, either a rich syrup or a solid sugar may be obtained. Or, instead of sulphuric acid, we may mix with the water 12 or 15 lb. of malt for every 100 lb. of starch; heat for three hours to 160° or 170° Fahr., and then filter and evaporate the syrup. Sugar thus prepared from starch has been called *maltose*. It much resembles in sweetness, chemical composition, and general properties, that of the grape. It does not always crystallise readily, however, and in this respect resembles the mixed sugars of honey. It is used for ordinary sweetening purposes, and for brewing and the manufacture of spirituous liquors. On the continent of Europe it is largely prepared for all these uses, but it is also now being made on a large scale in London. The syrup is extensively employed by the French confectioners, and brandy distilled from it is very generally drunk in northern Europe. The imports into the United Kingdom of this artificial sugar have risen rapidly of late. They were:—

In 1867, 8508 cwt; in 1870, 39,509 cwt; in 1876, 221,495 cwt

Instead of starch, woody fibre may be employed for the manufacture of this kind of sugar. Paper, raw cotton and flax, cotton and linen rags, and even sawdust, may be transformed into sugar by solution in strong sulphuric acid, dilution with water, and subsequent boiling. The operation is more complex and tedious, for the acid first changes the fibre into a kind of gum called *dextrine*, and then this dextrine further into sugar.

It is known that many sea-weeds, when boiled in water, yield a jelly which is wholesome, nutritious, and more or less agreeable to the palate. Among these are the well-known Carraigeen moss (*Chondrus crispus* and *Gigartina mamillosa*), which is collected in large quantities on the west coast of Ireland; and the Ceylon moss (*Plocaria candida*), which is exported from the islands of the Indian Archipelago to the markets of China. The jelly yielded by these plants, which are really sea-weeds, as well as by the Iceland moss and other

land lichens, is in like manner converted into grape-sugar when digested with sulphuric acid.

The number of vegetable substances, therefore, which by means of this acid can be transformed into the sugar of honey and fruits, is very great. The way in which these singular transformations of matters are brought about, will be illustrated at the close of the succeeding chapter.

II. THE CANE-SUGARS.—The plants or fruits which possess distinctly acid or sour juices, yield grape-sugar, though often accompanied by cane-sugar. Those which have little acid in their saps, contain for the most part cane-sugar. The chemical reason for this is, that, by the action of acid substances, cane-sugar is generally transformed into grape-sugar, even in the interior of the growing plant. The principal varieties of cane-sugar known in commerce are, cane-sugar properly so called, beet-sugar, palm or date sugar, maple-sugar, and maize-sugar.

Fig. 29.

Saccharum officinarum—
The Sugar-Cane.
Scale, 1 inch to 4 feet.

1°. *Sugar-Cane or Chinese Sugar.*—The sugar-cane (fig. 29) is still the chief source of the sugar of commerce, although an increasing quantity is obtained from beet. Theophrastus, Dioscorides, and Pliny, called cane-sugar the "honey of reeds;" Paul Egineta named it "Indian salt." But the sugar-cane was almost unknown to the Greeks and Romans. Now cultivated most extensively in America, it is a native of the Old World. It was familiar in the East in most remote times, and appears to have been cultivated in China and the South Sea Islands long before the period of authentic history. Through Sicily and Spain it reached the Canary Islands, thence was transplanted to St Domingo by the Spaniards in 1520, and from this island it has gradually spread over the

West Indies and the tropical regions of the American continent. It flourishes best where the mean temperature is from 75° to 77° Fahr.; but it thrives, and can be economically cultivated, where the mean temperature does not exceed 66° to 68° Fahr. Hence it is grown far beyond the tropics. And although the countries most productive in sugar, and which yield it at the least cost, lie for the most part within the torrid zone, and at low elevations,—yet the sugar-cane is profitably grown in some parts of the south of Europe; on the table-land of Nepaul, in India, at a height of 4500 feet; and on the plains of Mexico, as high as 4000 to 6000 feet above the level of the sea. It rarely ripens its seed, however, even in the most propitious localities. Young plants are raised, therefore, from portions of the stem planted for the purpose and when cultivated for sugar, they are rarely allowed to come to flower, as is represented in fig. 29.

There are many varieties of the sugar-cane, as there are of nearly all long-cultivated plants. In general, the varieties most common in each country and district are best adapted to the local climate and to the soils in which they grow. Those which yield the sweetest juice, and in the greatest abundance, if otherwise suited to the climate, are the most esteemed. In Louisiana, five different varieties are cultivated, one of the most elegant of which is represented in the annexed drawing (fig. 30). In each locality that variety is selected by the planter which he finds to give, on the whole, the most sure and profitable crop.[1] And so in our West India colonies the Tahiti cane was introduced as a new variety, because in the same time, and from the same extent of land, it yielded one-fourth more juice than the common varieties, while it produced also a larger and more solid growth of wood to be used as fuel.[2] The Batavian cane and the violet varieties from Java are also highly esteemed.

In Europe and most northern countries, cane-sugar is only an article of luxury, though one with which many would now find it difficult to dispense. In many tropical regions, however, the sugar-cane forms a staple part of the ordinary food. The ripe stalk of the plant is chewed and sucked after being made soft by boring it, and almost incredible

[1] American Patent Office Report, 1848, p. 281.
[2] Meyen—Geog. of Plants, p. 382.

quantities are consumed in this way. Large ship-loads of raw sugar-cane are daily brought to the markets of Manilla and Rio Janeiro; and it is plentiful in the markets of Barbadoes and New Orleans. In the Sandwich and many other islands of the Pacific, every child has a piece of sugar-cane in its hand; while in our own sugar colonies, the negroes become fat in crop-time on the abundant juice of the ripening cane. This mode of using the cane is, no doubt, the most ancient of all, and was well known to the Roman writers. Lucan (book iii. 237) speaks of the eaters of the cane as—

"Quique bibunt tenerâ dulces ab arundine succos"

—"And those who drink sweet juices from the tender reed." Travellers in the Himalayas find a piece of peeled sugar-cane a most refreshing *bon-bon*.

Fig. 30.

Striped Cane of Louisiana.

This nutritive property of the raw juice of the sugar-cane arises from the circumstance, that it contains, besides the sugar to which its sweetness is owing, a small but distinct proportion of gluten, as well as of those necessary mineral substances which are present in all our staple forms of vegetable food. It is thus itself a true food,[1] capable of sustaining animal life and strength without the addition of other forms of nourishment. This is not the case with the sugar of com-

[1] See "The Bread we Eat."

merce, which, though it in a certain sense helps to nourish us, is unable of itself to sustain animal life.

The sugar-cane varies in composition and richness with the variety of cane, the nature of the soil, the mode of cultivation, the character of the climate, and the dryness of the season. Its average composition in sugar plantations, when the canes are fully ripe, is about—

Sugar,	18
Water,	71
Woody fibre and carbohydrates,	$9\frac{1}{2}$
Saline matter,	$\frac{1}{2}$
Gluten and nitrogenous matter,	$\frac{1}{2}$
Colouring matters,	$\frac{1}{2}$
	100

The richness in sugar varies with many circumstances, and especially with what is called the ripeness of the cane. For it is a curious circumstance in the chemical history of this plant, that the sap sweetens only to a certain distance up the stem; the upper somewhat green part, which is still growing, yielding abundance of sap, but comparatively little sugar. One reason of this probably is, that the sugar in the upper part of the stem is rapidly transformed into woody matter, which is built into the substance of the growing stem and leaves. In consequence of this want of sweetness, the upper part of the cane is cut off, and only the under ripe part employed in the manufacture of sugar. In Louisiana, where the canes rarely ripen so completely as in the West Indies, the proportion of sugar contained in the juice is set down as low as 12 to 14 per cent.

For the extraction of the sugar, the canes are cut with a large knife, the labourer proceeding between the rows (fig. 31). The leaves and tops are then chopped off and left in the field, or used for fodder, while the under ripe part is carried to the mill. The yield of trimmed canes from an acre varies from 1 to 3 tons in fifteen months. These ripe canes are passed between heavy iron crushing-rollers, which squeeze out the juice. This juice is run into large vessels, where it is clarified by the addition of lime and other applications. The action of this lime is twofold. It removes or neutralises the acid which rapidly forms in the fresh juice, and at the same time combines with the gluten of the juice, and carries

it to the bottom. This gluten would act as a natural ferment, causing the sugar to run to acid. Its speedy removal, therefore, is essential to the extraction of the sugar. After being clarified in this way, and sometimes filtered, the juice is boiled rapidly down, is then run into wooden vessels to cool and crystallise, and finally, when crystallised, is put into perforated casks to drain. What remains in these casks is Muscovado or raw sugar; the drainings are well known by the name of molasses.

Fig. 31.

Cane Plantation in Louisiana.

Simple as this process is in description, it is attended with many difficulties in practice. It is difficult to squeeze the whole of the juice out of the cane—it is difficult to clarify the juice with sufficient rapidity to prevent it from fermenting, and so completely as to render skimming unnecessary during the boiling—it is difficult to boil it down rapidly without burning or blackening, and thus producing much uncrystallisable molasses—and, it is difficult afterwards to collect and profitably employ the whole of the molasses thus produced. These difficulties have been in great measure, by various improvements in the machinery and methods employed, overcome. More powerful presses are used, and the rollers revolve more slowly, and are often heated. Thus, of the 90 per cent of sweet juice which the cane contains, from 70 to 75 parts are expressed. Thus one-fifth of the sugar is left in the megass, or squeezed cane, which is used for fuel.

The molasses and skimmings are fermented and distilled for rum. But even of the molasses much is lost. The drainage from the raw sugar of the West Indies, while at sea, is stated at 15 per cent, and afterwards, in the docks, at 2 per cent—and further, the leakage of the molasses itself, which is shipped as such, is 20 per cent; so that of the uncrystallisable part of the sugar, also, there is a large waste. In the interior of Java, where fuel is scarce, the molasses is worthless, and is sent down the rivers in large quantities; but in the West Indies it has everywhere a market value, and may be distilled with a profit.

Further losses of sugar from the juice itself take place. Some is lost in the sediment formed, some in the scum and skimmings removed during the boiling. And when the juice has been boiled down to the crystallising point and is allowed to cool, much of the original sugar will have been converted into an uncrystallisable and syrupy form. This excessive production of "molasses" may be avoided by the use of vacuum pans in which the clarified juice is evaporated under a reduced pressure and consequently at a lower degree of heat.

By the use of better modes of clarifying, which chemical research has recently discovered—of charcoal filters before boiling, which render skimming unnecessary—of steam and vacuum boilers, by which burning is prevented, and rapid concentration effected—of centrifugal drainers to dry the sugar speedily and save the molasses—and of coal or wood as fuel where the crushed cane is insufficient for the purpose, —more and more planters in Java, in Cuba, and in our own colonies, are now extracting and sending to market 10 to 12 per cent of raw sugar from the 100 lb. of canes.

The total quantity of sugar annually extracted from the sugar-cane over the whole globe has been estimated at 5000 millions of pounds. Of this the largest proportion is yielded by the British possessions in the East and West Indies. The consumption in the United Kingdom amounted annually per head of the population, as an average deduced from three years at different periods to—

32 lb. in 1857, '58, '59: 41½ lb. in 1865, '66, '67: 62¼ lb. in 1875, '76, '77.

In 1849 the total produce of cane-sugar was 849,000 tons: it had risen to 1,880,000 tons in 1875. Our home consump-

tion approached 1,000,000 tons in 1877, but in this figure we do not distinguish between cane and beet sugar, which are identical in nature. The total imports of sugar were—

In 1867	Refined and candy,	834,452 cwts.
	Raw,	10,545,315 ,,
	Molasses,	358,316 ,,
In 1876	Refined and candy,	2,796,414 ,,
	Raw,	15,612,214 ,,
	Molasses,	498,441 ,,

The cane-sugars are popularly distinguished from the grape-sugars by greater sweetness or sweetening power. This is said to be greater in the proportion of five to three.[1] They also dissolve more readily in water. One pound of cold water dissolves 3 lb. of cane, but only 1 lb. of grape sugar. The solution is also thicker and more syrupy, less liable to change or run to acid, crystallises more readily, and gives a harder candy. These superior economical properties sufficiently account for the preference so universally given to this species of vegetable sweet.

Chemically, the cane differs from the grape sugars in containing less of the elements of water, in being charred or blackened by strong sulphuric acid (oil of vitriol), and in not readily throwing down the red oxide of copper from solutions of blue vitriol (sulphate of copper). By the action of diluted acids cane-sugar is converted into grape-sugar, and hence the reason why, as I have already said, cane-sugar is less abundant in plants which have acid juices, and why the souring of the cane-juice changes a portion of its crystallisable sugar into uncrystallisable syrup or molasses.

2°. *Beet-root or European Sugar.*—The root of the beet, and especially of the variety called the sugar-beet (fig. 32), contains often as much as an eighth part of its weight of sugar. By squeezing out the juice, as in the case of the sugar-cane, or by dissolving out the sugar from the sliced root and boiling down the solution, the raw sugar is obtained. In this state, the sugar possesses a peculiar unpleasant flavour, derived from the beet-root; but when thoroughly refined, it

[1] The sense by which we appreciate the sweetness of bodies is liable to singular modifications. Thus the leaves of the *Gymnema sylvestre*—a plant of Northern India—when chewed, take away the power of tasting sugar for twenty-four hours, without otherwise injuring the general sense of taste.

is indistinguishable in any respect from that of the sugar-cane.

The manufacture of this sugar is one of great and growing importance, especially in France, Belgium, Germany, and Russia. Its history also illustrates in a very striking way how chemical skill may overcome, as it were, the perversities of climate, and establish, upon an artificial basis, an important national interest, which shall successfully compete in the markets of the world with the most favoured natural productions of the choicest regions of the globe.

Fig. 32.

Sugar-Beet.
Scale, half an inch to a foot.

As early as 1747, Margraaf, in Berlin, drew attention to the large quantity of sugar contained in the beet, and recommended its cultivation for the manufacture of sugar. Fifty years later the attempt was made in Silesia, under royal patronage; but as only 2 or 3 per cent of crystallised sugar could be extracted, the work failed and was abandoned. Later, again, the Continental system of Napoleon I., which raised the price of sugar to five shillings (six francs) a pound, and especially the offer of a prize of a million of francs for the successful manufacture of sugar from plants of home growth, stimulated to new trials both in Germany and France. New methods, new skill, new machinery, and the results of later chemical research, were all applied, and, with the aid of high duties on foreign sugar, the manufacture struggled on through a period of very sickly infancy. In Germany fewer improvements were introduced at this time, so that the new manufactories erected in that country, during the reign of Napoleon, were one after another given up; but in France they became so firmly established, that even after the cessation of the Continental system few of them were abandoned. A more complete extraction of the sap, a quicker and easier method of clarifying and filtering it, and the use of steam to boil it down, enabled the French maker to extract

4 to 5 per cent of refined sugar from the 100 lb. of beet, and thus to conduct his operations with a profit. In this improved condition the manufacture, after a struggle of twenty years, returned again towards the north, and spread not only over Belgium and the different states of Germany, but over Poland, and through the very heart of Russia, as far as Odessa on the Black Sea. And quite recently the sugar-beet has been made the subject of experiment in Siberia, roots containing over 15 per cent of sugar having been grown there. At the present time, an immense quantity of beet-sugar is made in Europe. Not less than 1663 factories were at work in 1870, France and Russia having nearly 500 apiece.

The amount of beet-sugar produced in 1876 in five of the chief European beet-growing countries may be given, as—

France,	462,300	tons.
German Empire,	346,700	,,
European Russia,	245,000	,,
Austro-Hungary,	154,000	,,
Belgium,	79,000	,,

The sugar-beet has been successfully grown in Ireland and in several parts of England. Sugar has been made from it at Lavenham in Suffolk, and spirit of wine at Buscot near Faringdon.

The average composition of the root of the sugar-beet of France, Belgium, and the Rhenish provinces, is nearly as follows:—

Sugar,	$10\frac{1}{2}$
Gluten,	$\frac{1}{2}$
Fibre &c.,	5
Soluble organic compounds,	$1\frac{1}{2}$
Ash or mineral matter,	1
Water,	$81\frac{1}{2}$
	100

But this proportion of sugar varies very much. Thus it is greater,—

a. In small beets weighing about $1\frac{1}{2}$ lb. than in large,—the larger beets being also more watery.

b. In some varieties, produced by careful selection and cultivation.

c. In dry climates, and especially where the climate or season is dry after the roots have begun to swell.

d. In light potato or barley than in heavy soils.

e. In the part under than in that above ground.

f. When manure has not been directly applied to the crop.

These facts show how much practical agriculture has to do with the success of this important manufacture. The difference of climate, soil, and mode of culture, have so much effect, that, while the beets of Lille, a southern centre of the manufacture, do not average more than 10 to 12 per cent of sugar, those of Magdeburg, a more northern centre, contain from 12 to 14 per cent. Under certain very favourable conditions, as much as 18 per cent of sugar has been found in the beet of North Germany. The proportion of sugar is so much less in the part that grows above ground, that it is always cut off to feed cattle. This reminds us of the want of sweetness in the upper part of the sugar-cane (p. 186), and the reason is probably the same in both cases, that the sugar is in these parts transformed into woody matter.

The average proportion of sugar extracted in Belgium and France is 7 lb. from every 100 of fresh root. In Germany, the average yield varies between 8 and 9 lb. from 100 lb. of roots.

Several modes of extraction are in use. The root is pulped, or sliced, and the juice in it extracted either by pressure or by centrifugal force, or it is washed out by water. An excellent method consists in allowing the sugar to diffuse out into water. The clear juice obtained by any of these processes is treated with lime, heated, filtered, carbonic acid gas passed through to separate lime, boiled, allowed to settle, filtered through animal charcoal, boiled down by steam to the crystallising point, and then, as in the case of cane-sugar, cooled and drained from the molasses. From the beet, the molasses thus obtained is colourless, but it has a disagreeable taste, and cannot, therefore, like cane-molasses, be directly employed for any sweetening purpose. The raw sugar has also an unpleasant taste, and is in consequence refined, for the most part, before it is brought to market.

It is interesting to remark how new improvements in this manufacture constantly make known new chemical difficulties, and present new chemical and agricultural problems to be solved. The first great difficulty was, to prevent the fermentation of the juice, the production of acid, and the simultane-

ous waste of sugar and conversion of a part of it into uncrystallisable syrup. The second was, to boil it down so as to prevent burning, and the production of uncrystallisable molasses. The former has been overcome by various chemical means, as the use of sulphurous acid or its compounds,[1] and the latter by the use of steam. But as the yield of sugar approached to 7 per cent, it was found that certain syrups remained behind, which, though they certainly contained cane-sugar, refused stubbornly to crystallise; and the reason of this was traced to the presence of saline matter, chiefly common salt, in the sap. This salt forms a compound with the sugar, and prevents it from crystallising. And so powerful is this influence, that 1 per cent of salt in the sap will render 3 per cent of the sugar uncrystallisable. To overcome this difficulty, new chemical inquiries were necessary. As results of these inquiries, it was ascertained—

First, That the proportion of sugar was larger, and of salts less, in beets not weighing more than 5 lb. The first practical step, therefore, was, that the sugar-manufacturers announced to the cultivators who raised the beet, that in future they would give a less price for roots weighing more than 5 lb.

Next, That a crop raised by means of the direct application of manure contained more salt, and gave more uncrystallisable syrup, than when raised without direct manuring. A larger price, therefore, was offered for roots grown upon land which had been manured during the previous winter; a higher still for such as were raised after a manured crop of corn; and a still higher when, after the manuring, two crops of corn were taken before the beet was sown. Recent experiments have, however, shown that although some manures, as nitrate of soda and guano, do increase the salts of beet injuriously, moderate doses of superphosphate are not prejudicial.

Thus the difficulty was lessened by chemico-agricultural means; and though the crop was less in weight to the farmer, the higher price he obtained in some degree made up the difference.

[1] Sulphurous acid is the name given by chemists to the strong-smelling fumes given off by burning sulphur. In one proportion, it forms with lime *sulphite of lime;* in twice this proportion, it forms *bi*-sulphite (*bis* twice). This bisulphite is soluble in water, and a little of the solution added to the weak sugary liquors prevents them from fermenting.

In France and Belgium, the crops gathered average 14 or 15 tons an acre, while about Magdeburg they do not exceed 10 or 12 tons. But the latter are richer in sugar, and poorer in salts, in proportion. It should be stated that these salts are now extracted and purified in special chemical works. Beets yield, in fact, four distinct products—

1. Crystallised sugar.
2. Exhausted pulp, very useful for cattle-food.
3. Alcohol obtained by fermentation from the uncrystallisable sugar.
4. Potash-salts.

One other point in this history is very interesting, as illustrative of the way in which a tax upon manufacturing industry may be made actually to promote, instead of retarding its advancement! The tax on beet-sugar within the bounds of the former German Customs Union (Zollverein), was levied, not on the sugar actually produced, but upon the weight of raw beets employed by the manufacturer. It was assumed that the roots would yield 5 per cent, or one-twentieth of their weight of sugar; and then upon every 20 cwt. of roots a tax of two dollars was imposed. According to the assumed yield of sugar, this was equal to a tax of two dollars on every hundredweight of sugar. But in reality it was much less. By the improved methods, one of sugar was soon extracted from about twelve of the root; and the more he could extract, the less duty in proportion the manufacturer paid. Thus he was continually stimulated to improve his methods. The absolute gain which he derived from an increased produce per cent, was enhanced by the peculiar satisfaction which arose from the consciousness that every additional pound he extracted was to him duty free.

And the profit he thus makes is at the same time a source of gain to others. It is the character of all scientific progress, that an advanced step taken in one country is at once a signal for similar steps in other countries, and an assurance that they will by-and-by be taken. Thus the improvements which arose out of the fiscal regulations of the German Zollverein were gradually introduced into the boiling-houses of Cuba, and they, with other improvements, are making more perfect and profitable the planting operations of our own West India colonies.

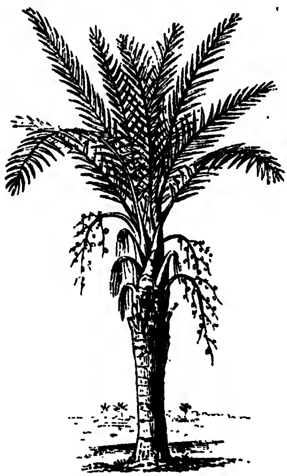
3°. *Palm or Date Sugar*, or Jaggery.—Most trees of the

palm tribe, when their top-shoot, or spadix as it is called, is wounded, yield a copious supply of sweet juice. When boiled down, this juice gives a brownish raw sugar, known in India by the name of jaggery. The following are the chief sugar-producing palms :—

Palmyra palm, *Borassus flabelliformis;* Ceylon, India, Central Africa.
Talipot palm, *Corypha umbraculifera;* Ceylon.
Date palm, *Phœnix dactylifera;* N. Africa, W. Asia.
Toddy palm, { *Phœnix sylvestris;* *Caryota urens;* } India.

The gommuti palm (*Saguerus saccharifĕr*), fig. 33, is still more productive, and, in the Moluccas and Philippines, yields much sugar. The sap of the cocoa-nut tree is boiled down in the South Sea Islands till it has the consistence of a brown syrup, resembling very much the molasses which drains from raw cane-sugar; but the wild date-palm, or toddy or wine (*Phœnix sylvestris*), is the largest known sugar-producer. From this tree it is said that 60,000 tons,[1] or 130,000,000 lb. are yearly extracted. Of this quantity, 5000 tons, or 11,000,000 lb., are extracted in Bengal alone. Indeed the chief production as well as consumption of this date-sugar is in India. A good deal of it is imported into this country, sometimes under its true name of jaggery, or East India date-sugar, but often, also, under that of cane-sugar. These sugars are worth in the London markets about 13s. to 15s. per cwt.

Fig. 33.



Saguerus saccharifer—The Gommuti Palm.
Scale, 1 inch to 20 feet.

This palm-sugar, indeed, from whichever of the trees it is extracted, is exactly the same species of sugar as is yielded by the sugar-cane. It differs chiefly in the flavour of the molasses which drains from and colours the raw sugar. When refined, it cannot be distinguished from refined West India

[1] Archer's Popular Economic Botany, p. 140.

sugar. The flavour of the molasses is not unpleasant, so that it is readily eaten by the natives of the various tropical regions in which the palm-trees grow.

The total known produce of palm-sugar is estimated at 150,000 tons. This is about one-twenty-fourth part of all the cane-sugar extracted for useful purposes.

Other non-acid fruits, like the melon, the chestnut, and the cocoa-nut, contain cane-sugar, but it is not extracted from them as an article of commerce.

4°. *Maple or North American Sugar.*—The sugar-maple (*Acer saccharinum*), fig. 34, grows abundantly in the northern parts of New England, along the lakes and in the British provinces of North America. Three other American species of maple also yield sugar. The four States of New Hampshire, Vermont, New York, and Michigan produce together upwards of 20,000,000 lb., and the Canadas together about 7,000,000 lb. of maple-sugar. In 1870, 1,500,000 lb. were produced in Pennsylvania. The settlers generally, when they clear their virgin farms, reserve a few trees to make sugar for the use of their families; but, in many places, extensive natural forests of maple-trees still cover fertile tracts of uncultivated country, and there the sugar is manufactured in large quantities. The average yield of each tree is estimated in Lower Canada at 1 lb; and the right of making the sugar is there rented out by the proprietor at one-fifth of the supposed produce, or 1 lb. of sugar for every five trees. When the month of March arrives, the sugar-makers start for the

Fig. 34.

Acer saccharinum—The Sugar-Maple.
Scale, 1 inch to 30 feet.
Leaf, 1 inch to 5 inches.

forest, carrying with them a large pot, a few buckets and other utensils, their axes, and a supply of food. They erect a shanty where the maple-trees are most numerous, make incisions into as many as they can visit twice a-day for the purpose of collecting the sap, boil down this sap to the crystallising point, and pour it into oblong brick-shaped moulds, in which it solidifies. In this way, in the valley of the Chaudière, from 3000 to 5000 lb. of sugar are sometimes made during the season of two months by a single party of two or three men.

It is a singular circumstance in the chemical history of the sap of this tree, that the first which flows for some time after the incision is made, is clear, colourless, and without taste. After standing a day or two, this sap becomes sweet; and a few days after the sap has begun to run, it flows sweet from the tree. The average percentage of sugar in the sap does not exceed 2. The last sap which the tree yields is thick, and makes an inferior sugar. When boiled carefully in earthenware or glazed pots, the clear sap gives at once a beautifully white sugar, and especially if it be drained in moulds and clayed, as is done with common loaf-sugar. In this pure white condition it is not to be distinguished from refined cane-sugar. It is identical with pure cane-sugar in all its properties.

For domestic use it is generally preferred of a brown, and by many of a dark-brown colour, because of the rich maple flavour it possesses. This flavour, though peculiar, and therefore new to a stranger in North America, soon becomes very much relished. The brown sugar is an article of regular diet among the Lower Canadians. On fast-days, bread and maple-sugar, or maple-honey, as the molasses of this sugar is called, are eaten in preference to fish. In spring, when plentiful, it sells as low as 3d. a-pound: in winter it rises sometimes as high as 6d.[1]

It is an interesting character of the maple-juice, when boiled to the crystallising point, that the molasses which drains from it is agreeable to the taste, and is relished as a domestic luxury. In this respect it is superior even to the molasses of the sugar-cane. Were beet-root molasses eatable in a similar way, the manufacture of beet-sugar would have had fewer

[1] See the Author's Notes on North America, vol. i. p. 303.

difficulties to overcome; and it would have been now both easier to conduct and more profitable in its results.

The total production of maple-sugar in 1850 was estimated at 45,000,000 lb., or the one hundred and twenty-fifth part ($\frac{1}{125}$) of the whole quantity of cane-sugar then extracted for the use of man. The manufacture of maple-sugar diminishes yearly in proportion as the native American forests are cut down.

5°. *Maize or Mexican Sugar.*—The green stalks of maize or Indian corn contain a sweet juice, which, when boiled down, yields an agreeable variety of cane-sugar. This sugar was known and extracted by the ancient Mexicans, and was in use among them prior to the Spanish invasion. For this reason I have distinguished it as Mexican sugar.

The manufacture of this sugar has been attempted of late years in the United States, and many persons have successfully extracted a sufficiency for their domestic consumption. It has not hitherto, however, been prepared in such quantity, or at such a price, as publicly to compete in the market with sugar from the cane; but there seems no reason why this branch of industry should not be successfully prosecuted, especially in those States of the North American Union which are known to be more eminently favourable to the growth of maize.

The extraction of sugar from this plant has also been attempted in southern Europe. A manufactory of it in the south of France, in the neighbourhood of Toulouse, produced about 20,000 lb. of sugar a-year.

6°. *Sorghum-Sugar.*—In China, under the name of "sugar-cane of the north," a species of sorghum is cultivated for the extraction of sugar. This plant is allied to the *Sorghum vulgare*, or dhurra plant (fig. 13), of which a description has already been given.[1] This plant was introduced into France, and experiments made upon it by M. Vilmorin. He states that it is capable of yielding, on an average, from an acre of land, 26,000 lb. of juice, containing from 10 to 13 per cent of sugar; and that this is more than the average yield of the sugar-beet. It is alleged, however, that the plant is adapted to only a few parts of the south of France. *Gynerium saccharoides*, a Brazilian grass, is another sugar-yielding plant.

[1] See "The Bread we Eat," p. 77.

The estimated yearly production of sugar from its four chief sources may be set down as probably near the following figures :—

	Tons.	Percentage of the whole production.
Cane-sugar,	2,140,000	59.2
Beet-sugar,	1,318,000	36.5
Palm-sugar,	150,000	4.1
Maple-sugar,	5,000	.2
Total,	3,613,000	100.0

The annual consumption of sugar per head in 16 European states is represented by these figures :—

	lb.		lb.
United Kingdom,	63	Austro-Hungary,	15
Denmark,	33¼	Norway,	12¾
Holland,	25	Portugal,	8½
Belgium,	23¼	Greece,	6½
Sweden,	17	Russia,	5½
German Empire,	16½	Turkey,	3¾
Switzerland,	16	Italy,	3½
France,	15½	Spain,	0½

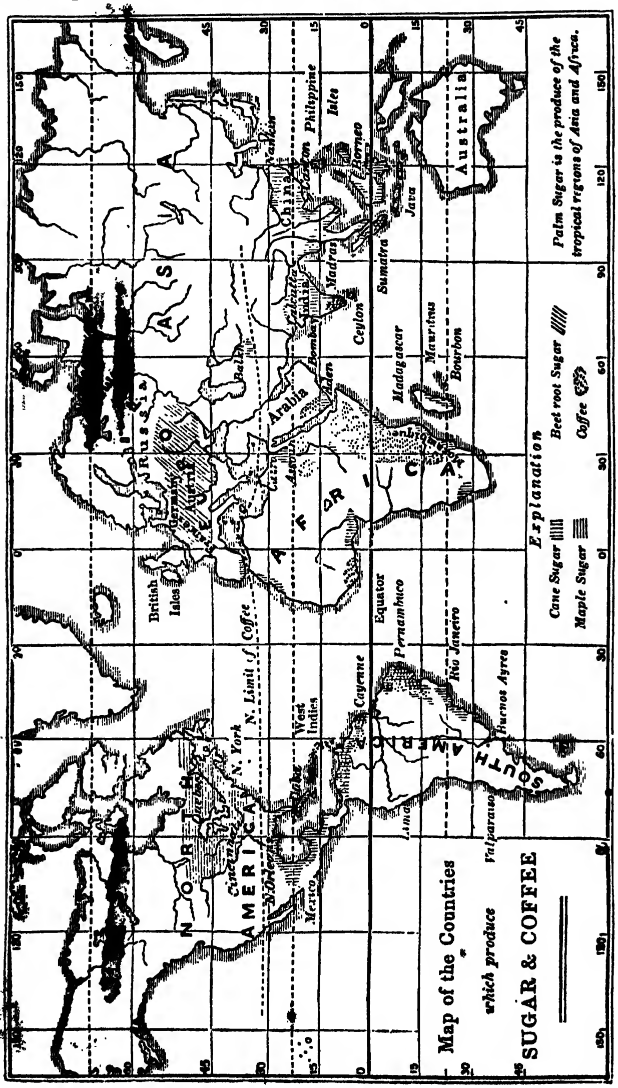
In the United States the consumption per head is 37¾ lb.; in British America, 51½; and in Australia, 86.

The accompanying map represents to the eye the several parts of the world in which cane, maple, and beet sugar are chiefly extracted. (*See* p. 200.)

Wide differences exist among the quantities consumed per head in different countries—that of Russia being very low, and that of Venezuela being stated as 180 lb. annually! In 1835 the yearly consumption of sugar per head in Great Britain was but 17¼ lb.; in 1876 it had risen to 63 lb. With the peculiar circumstances which occasion so large a consumption in Venezuela I am unacquainted. Refined sugar is shipped to that country largely from Europe.

Of course much of the sugar produced is ultimately fermented and changed into spirit, and so can no longer be reckoned as food. But that which is directly consumed as a food does serve to maintain the heat and activity of the body. One physiological effect of cane-sugar appears to be the lessening of the waste of phosphates, and the increase of their absorption. In the young the production of bone, and in the old its conservation, may be thus beneficially influenced. But

its great use is as a giver of heat and energy, and one more easily digested than fat or even starch.



Before leaving this part of my subject, I may be permitted, in the interest of chemical science, to ask my reader to reflect—

1°. How important an interest, economical and social, the history of sugar-extraction exhibits to us as depending directly upon chemical research and progress, and upon the diffusion and application of chemical knowledge.

2°. How largely successive applications of this branch of knowledge have already benefited the manufacture of sugar, and aided in bringing this luxury within the reach of the poorer classes.

3°. And especially, how chemistry has earned the deserved gratitude of the European continent, by giving it an entirely new industry, and by making it independent of foreign countries for one of the most esteemed and now almost necessary luxuries of life.

CHAPTER XI.

THE SWEETS WE EXTRACT.

THE MANNA AND MILK SUGARS.

Manna-sugars; their sensible and chemical characters.—Manna of the ash; its composition and uses.—Occurrence of manna-sugar in sea-weeds.—Gum-tree manna.—Other mannas.—Oak, larch, and cedar mannas.—Persian manna.—The alhagi and tamarisk mannas.—The manna of the Scriptures; trees supposed to produce it.—The real manna not known.—Liquorice-sugar.—Milk-sugar.—Analogies in the composition of cane, grape, and milk sugar.—How the two former are produced from each other, from starch, and from humic acid.—What chemists understand by chemical reactions.—How a knowledge of these improves old and gives rise to new chemical arts.—Illustration in the manufacture of sugar, glass, and dyes.

III. THE MANNA-SUGARS form a third class of sugars which are distinguished from the grape and cane sugars by three principal characters. *First*, by their chemical composition; *secondly*, by their inferior sweetness; and *thirdly*, by their not fermenting when mingled with yeast. Of this class, also, there are several varieties.

1°. *Manna of the Ash.*—Two species of ash, the *Fraxinus ornus*, and the *F. rotundifolia*, yield this kind of sugar. The European supply is chiefly derived from Sicily and Calabria. The *F. ornus*, a small tree of 20 to 25 feet high, is there cultivated in plantations for the purpose. In the months of July and August, when the production of leaves has ceased, the sap is drawn from the tree. For this purpose, cross cuts, about 2 inches long (fig. 35), are made in the

stem, beginning at the lower part near the soil. These are repeated every day in warm weather, extending them perpendicularly upwards along the one side of the tree, leaving the other to be cut in the following year. The sap flows from these incisions, and is sometimes collected in vessels, and sometimes allowed to harden on the outside of the tree. It is very rich in sugar, and speedily concretes in fine weather into the manna of commerce. The quality of the manna varies with the age of the tree, and with the part of the stem (lower or higher) from which it flows, and with the period of the season in which it is extracted. From the upper incisions, from trees of middle age, and in the height of the season when the sap flows most freely, the flake manna, most esteemed in England, is obtained in largest quantity.

Fig. 35.

Fraxinus ornus—The Manna Ash, and the mode of collecting the manna.

Manna—besides a variable proportion of gum, which in some varieties amounts to a third of its weight—contains two kinds of sugar. The larger proportion consists of a peculiar, colourless, beautifully crystalline sugar, to which the name of *mannite* is given. This forms from 30 to 60 per cent of the whole manna, and is properly *the* manna-sugar. Mixed with this there is from 5 to 10 per cent of a sugar resembling that of the grape, and which ferments with yeast.

When newly extracted, manna is found to be nutritious, as well as agreeable to the taste; and a considerable quantity of it is used as food, especially in Calabria. As it becomes old, however, it acquires a mild laxative quality, when taken in doses of an ounce or two, which unfits it for use as a part

of the ordinary diet. This latter quality recommends it for use as a medicinal agent, for which purpose it is exported to various parts of Europe. The quantity yearly imported into Great Britain amounts to about 11,000 lb., nearly all of which comes from Sicily.

This medicinal quality does not reside in the mannite or true sugar of manna, but in the other matters with which it is contaminated. By itself, in the pure or refined state, this sugar has no appreciable medicinal action, and, were it abundant and cheap, might be employed for ordinary sweetening purposes. It is less sweet than cane-sugar, and may be crystallised from hot spirit. It dissolves in about five parts of cold water.

It is a singular fact that this peculiar manna-sugar exists in many familiar sea-weeds. It gives their sweet taste to those which are collected for eating along various parts of our coasts, and is found in smaller quantity in many which are not perceptibly sweet to the taste. The *Laminaria saccharina*, when quite dry, contains above 12 per cent, or one-eighth part of its weight, of mannite. When the plant is dried in the air, the sugar exudes, and forms a white incrustation on its leaves. The *Halidrys siliquosa* contains from 5 to 6 per cent, and even the common *Fucus vesiculosus* 1 or 2 per cent (STENHOUSE). No use is made of this sugar of sea-weeds, except in so far as it assists, in some cases, in making them eatable.

Mannite in small quantity may also be extracted from many kinds of fungi, from common celery, and from the root of the dandelion; and it can be formed artificially from cane and fruit sugar.

2.° *Eucalyptus Sugar, or Gum-tree Manna.*—The genus Eucalyptus, or gum-tree of the colonists (fig. 36), forms a distinguishing feature in the landscape and forest scenery of Australia and Van Diemen's Land. At certain seasons of the year, a sweet substance exudes from the leaves of these trees, and dries in the sun. When the wind blows so as to shake trees, this Australian manna is sometimes seen to fall like a shower of snow. Like the true manna, this sweet substance contains a peculiar crystallisable sugar (*melitose*)—different, however, in composition and in some of its properties, from the mannite already described.

3°. *Other Mannas.*—Other sweet substances also are obtained from plants, to which the name of manna has been given; but these products contain a variety of different sugars, some closely related to true manna-sugar, and some to grape-sugar. Thus a peculiar sugar, called *quercite*, has been extracted from acorns, and from a palm, the *Chamærops humilis:* another kind, known as *pinite*, from the leaves of *Pinus Lambertiana.* A kind of oak-manna exudes from the leaves of a species of oak common in Kurdistan, and known to botanists as the *Quercus mannifera*, or manna-bearing oak. Larch-manna is a sweet substance which, in some countries, is found upon the European larch (*Larix europæa*) about the month of June. Cedar-manna occurs in small globules on the branches of the *Cedrus libani.* It is brought from Mount Lebanon, where it sells as high as 20s. or 30s. an ounce. It is much esteemed in Syria as a remedy for affections of the chest. Persian manna, or *Gen*, called also Alhagi manna, and by the Arabs *Tereng jabim*, is obtained from the camel's thorn (*Hedysarum alkagó*), a plant which is indigenous over a large portion of the East. It yields manna, however, only in Persia, Bokhara, Arabia, and Palestine. Extensive plains are in these countries covered with alhagi, and it is of great importance as food for the camels, as well as for sheep and goats. From the wounds produced by the browsing of these animals the manna chiefly exudes. It is collected by the Arabs and caravans which cross the Desert, and is used as food. It is gathered by merely shaking the branches.

Fig. 36.

Eucalyptus resinifera—The Iron Bark Gum-tree.
Scale, 1 inch to 60 feet.
Leaves, 1 inch to 5 inches.

Tamarisk-manna is obtained from the *Tamarix mannifera*, a tree which grows abundantly in the neighbourhood of Mount Sinai. The manna of the Old Testament is supposed by some to have been that of the camel's thorn, and by others that of the tamarisk. Both trees grow in the wilderness of Sin, along certain parts of the route of the ancient Israelites, and both yield limited supplies of a sweet manna. If the produce of either of these trees was the true manna of the Israelites, the miracle by which they were so long fed with it consisted—*first*, in a wonderful multiplication of the produce, so as to sustain millions where probably not a score of persons could be sustained on the quantity naturally produced; and, *secondly*, in causing it to follow and fall daily around them in parts of the wilderness where none of the trees grow, and in equal abundance all the year round. That is to say, the sustenance of the wandering people was the result of a constant miracle, whether the manna was of a kind which might or might not have been derived from either of these natural sources.

Fig. 37.

Tamarix gallica mannifera—The Manna-bearing Tamarisk. Scale, 1 inch to 12 feet. Flowering branch, 1 to 5 inches.

In the Wady Feiran—the valley which leads from the Gulf of Suez towards Mount Sinai—the traveller passes through thick avenues of Tarfa trees (*Tamarix mannifera*, fig. 37), bending over his head like the alleys of a garden. This tree "resembles the weeping birch, but is still more delicate in appearance, and the so-called manna flows in drops from the extremities of its slender pensile boughs. A small quantity is collected and carried to the convent of Sinai, where it is prepared by boiling and put into small tin cases, which are disposed of to pilgrims and other visitors. In this state it resembles melted gum with small rounded grains in it, and has a somewhat similar taste, only sweeter and rather aromatic." [1] The manna is supposed to

[1] Bartlett's Forty Days in the Desert, p. 68. The figure I have given does

flow in consequence of the puncture of the *Coccus manniparus*, an insect which infests the tamarisk-trees. It exudes as a thick syrup, which, during the heat of the day, falls in drops, but during the night congeals, and is gathered in the cool of the morning. Its solution in water readily ferments. It is eaten in Palestine and about Sinai as a delicacy, and, like the cedar-manna, is esteemed as a remedy in diseases of the chest. The total quantity of this manna now collected in the desert of Sinai appears to be comparatively trifling.

Dr Milman and Dr Lepsius both regard this sweet substance as the manna of Scripture, and consider its properties to be generally the same as those ascribed by Moses to that collected by the children of Israel. Dr Robinson, on the other hand, denies that their properties at all correspond. I agree with Dr Robinson. In doing so, however, I do not lay so much stress on alleged differences in taste, in general appearance, &c., as on the very remarkable property mentioned in the following passage:—

"And Moses said, Let no man leave of it till the morning. Notwithstanding they hearkened not unto Moses; but some of them left of it till the morning, and it bred worms, and stank: and Moses was wroth with them."—(Exodus xvi. 19, 20.)

This rapid putrefaction, the smell, and the breeding of worms, are properties which belong to no known variety of sweet vegetable exudation. It implies something of an animal nature, or the presence in considerable quantity of a substance analogous to the gluten of plants or the fibrin of animals.[1] And the presence of such a substance, again, accounts for the very nutritious quality ascribed to this manna, and which is so superior to that of any other vegetable sweet with which we are acquainted. The manna of Scripture, therefore, I believe to be still unknown, as well as the immediate or natural source from which it might have been derived.

Orcin Manna.—Orcin is a sweet substance which exists ready formed in some lichens, and may also be obtained by

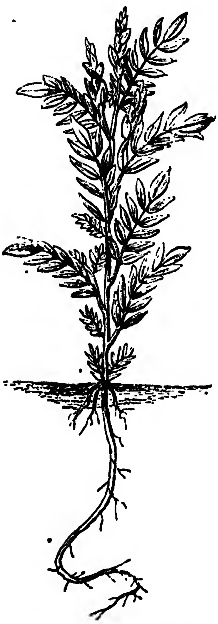
not represent the graceful tree described by Bartlett. It varies in appearance in different localities, and I cannot find that any representation of the entire tree has anywhere been published. In a book so beautiful as Mr Bartlett's one might have expected to find this tree, which he describes so graphically.

[1] See "The Beef we Cook."

the chemical treatment of allied substances present in these plants. In chemical composition and properties it is very different from any of our common sweets, and it has a disagreeable after-taste, which would alone prevent it from finding a place among the luxuries of life.

IV. LIQUORICE-SUGAR.—The root of the common liquorice (*Glycyrrhiza glabra*), fig. 38, contains a peculiar yellow, uncrystallisable, sweet substance, which, when united with an alkali, becames dark-brown. The dried extract is known in this country under the names of Spanish and Italian juice, from the countries in which it is most abundantly produced; it is also grown in Russia. It differs in flavour from all the other sugars I have mentioned; it does not crystallise, and it does not ferment when yeast is added to it. It is called glycyrrhizin, and contains in 100 parts —carbon, 61.5; hydrogen, 7.6; and oxygen, 30.9.

Fig. 38.



Glycyrrhiza glabra—The Liquorice-plant. Scale, half an inch to a foot.

For medicinal purposes the root is largely cultivated at Mitcham in Surrey, and other places. The extract is imported partly in the sticks, known under the name of Spanish Liquorice; and partly in solid masses, run into boxes containing about two hundredweight each. In 1850 about 500 tons were imported. In 1867 the imports were 1676 tons; and in 1876 they were 1096 tons. It does not compete directly, however, with cane-sugar. A considerable quantity, no doubt, is eaten as a sweet, and to give relief to affections of the throat, but the principal consumption is said to be by the brewers in the manufacture of porter.

The roots of *Glycyrrhiza echinata* and *G. glandulifera*, of *Trifolium alpinum*, and of *Abrus precatorius*, are said to possess the same properties as the common liquorice; and among other

sweets which resemble that of liquorice, is one which is found in the root of the *Ononis spinosa.*

V. Milk-Sugar.—Milk contains a peculiar species of sugar, to which the sweetness of milk is owing. When the curd is separated in the making of cheese, the sugar remains in the whey, and may be obtained in the form of crystals by boiling the whey to a small bulk, and setting it aside to cool. This sugar crystallises; it is hard, gritty, and rough when crushed between the teeth, and is less soluble and less sweet than grape-sugar. In Switzerland and some other cheese countries it is extracted for sale, but the manufacture and consumption of milk-sugar is on the whole very trifling. In the preparation of the pilules and globules of the homœopaths it is, however, employed, while it forms a desirable addition to the diluted cow's milk used in feeding very young children. There are about 5 parts of milk-sugar in 100 of cow's milk, while woman's milk contains 7 per cent. In plants, milk-sugar rarely occurs, —the acorn being almost the only common vegetable production in which it has as yet been detected.

Among the most important of the varieties of sugar above described—the grape, fruit, cane, and milk sugars—there exists a remarkable analogy in chemical composition. They all consist of the three elementary bodies already described under the names of Carbon, Hydrogen, and Oxygen.[1] And in all of them the hydrogen and oxygen are in the proportions to form water, so that we can, for simplicity of language, say that they are composed of carbon and water. The proportion of this water is not the same in each variety of sugar, neither is it always different. Comparing together quantities of various sugars which contain 12 atoms of carbon, the porportion of water in each kind will be—

	Carbon.	Water.
Cane-sugar and dried milk-sugar, . .	144	198
Grape, fruit, and starch sugar, . .	144	216
Milk-sugar, ...	144	216

Or, simplifying these numbers as far as possible, we find—

72 lb. of carbon and 99 of water form 171 lb. of cane or dried milk sugar.
72 „ 108 „ 180 lb. of grape, fruit, starch, and crystallised milk sugar.

[1] See Chaps. I. and II., "The Air we Breathe," and "The Water we Drink."

The proportions of carbon and water in crystallised cane and milk sugars are identical; and yet between these two kinds of sugar the difference of properties is equally great. This last is a very remarkable circumstance, and presents the first example which has fallen in our way of one of the most interesting discoveries of modern chemistry—that two compound substances may consist of the same elementary bodies united together in the same proportions, and yet be very different from each other in their properties.

Other kindred illustrations of this principle are presented by cellular tissue (cellulose), starch, and dextrine, which, as I have explained (p. 182), may be artificially converted into grape-sugar by the action of weak sulphuric acid. Thus—

72 lb. of carbon united to 90 lb. of water, form 162 lb. either of cellulose, of starch, or of dextrine.

And yet each of these three substances is very different in its properties from either of the other two.

Now, regarding substances so composed, it is not difficult, with the aid of this knowledge, to form a general idea of the way in which they may be transformed, one into the other. Thus—

162 of starch, with 18 of water, *may* form 180 of grape-sugar.
342 of cane-sugar, with 18 of water, *may* form 360 of grape-sugar.

And changes of this kind really take place in nature. The starch of the tasteless pear, of the banana, and of the bread-fruit (p. 85), changes into sugar as the fruit ripens and becomes sweet. And by the action of acids in the sour saps of plants, and in somewhat acid fruits, cane-sugar, which is first produced, is changed into grape-sugar. In all these cases, the substance which disappears only combines with a little more water to form the new compound which is produced.

And we artificially imitate these natural operations when, in the manufacture of potato-sugar, we transform the starch of the potato into a sweet resembling the sugar of grapes, or when, by the prolonged action of sulphuric acid, we change sawdust or rags into a similar sweet.

In these changes, the acid employed possesses the singular property of causing cellulose or starch to unite with a larger proportion of the elements of water, and thus to assume the form of grape-sugar. And it is out of such observed

reactions of bodies—as such influences are called—that new chemical arts are daily springing up. Thus the manufacture of potato-sugar, already described, is a valuable independent art, founded solely upon a knowledge of this action of sulphuric acid. But many other arts, besides, have been either wholly based upon or have been greatly improved by the application of this property. It has, for instance, been employed in the purification and preparation of the colouring matter of madder-root[1] (*Rubia tinctorum*).

Thousands of similar reactions are known to chemists; and the origin of almost every art of life may be traced to the first observation of some one of the countless visible influences which one form of matter exercises over another.

Melted soda dissolves sea-sand, and the solution, when cold, is our common window-glass. Hence the magnificent glass-trade of our time.

Potash melted with hoofs and horns, and thrown carelessly into water containing iron, gave an intense blue colour. This was Prussian blue; and hence a crowd of arts and manufactures, and of beautiful applications of chemistry, have sprung up.

Every day new arts sprout up, as it were, beneath our feet, as we linger in our laboratories observing the new reactions of probably new bodies; and in each new art is seen a new means of adding to the comforts and luxuries of mankind, of giving new materials and facilities to commerce, and of increasing the power and resources of nations.

For pleasing examples of such arts—just bursting into leaf like the buds before our eyes in the sunshine of our English spring—I refer the reader to a succeeding chapter on "The Odours we Enjoy," and to another entitled "The Colours we Admire."

[1] See "The Colours we Admire."

CHAPTER XII.

THE LIQUORS WE FERMENT.

THE BEERS.

Our fermented drinks.—Grape-sugar is changed into alcohol by fermentation. —Cane-sugar and starch converted into alcohol.—Production of diastase during the sprouting of corn.—Action of this substance upon starch.—How the infant plant is fed.—Malt-liquors, principles involved in the preparation of.—The malting of barley.—The making of beer.—Influence of diastase on the processes.—The fermentation of the wort.—Influence of the yeast.—How the yeast-plant grows and multiplies; its remarkable influence still inexplicable.—Composition of beer.—Proportions of malt-extract and of alcohol.—Beer characterised by its nutritive quality and its bitter principle. Chica or maize-beer of South America.—Maize-malt.—Preparation of chica mascada, or chewed chica.—How the chewing promotes the process and gives strength to the chica.—Influence of the saliva.—Chica from other vegetable substances.—Bouza or millet-beer of Tartary, Arabia, and Abyssinia.—Murwa-beer of Himalayas.—Chemical peculiarities of these millet beers.—Quass, or rye-beer.—Koumiss, or milk-beer; mode of preparing it; its composition and nutritious qualities.—Lactic acid in this beer.—Ava, cava, or arva.—Extensive use of this drink among the South Sea Islanders; how it is prepared and used; its narcotic qualities.—Effect of chewing on the ava-root.—Ceremonies attending its preparation and use in the Tonga and Fiji Islands.—Saké or rice-beer of Japan; its manufacture.

THE liquors we ferment are all directly produced either from the natural sugars which we extract from plants, or from the sugars which we prepare by art. I shall briefly advert to the most interesting and important of these liquors now in use in different parts of the world. The way in which these drinks are prepared, their chemical composition, and their chemico-physiological action upon the system, are

more or less connected with the common life of almost every people.

I. THE BEERS.—When grape-sugar is dissolved in water, and a little yeast is added to the solution, it begins speedily to ferment. During this fermentation the sugar is split up into two different substances—alcohol, and carbonic acid.[1] The former remains in the liquid, while the carbonic acid gas escapes in bubbles into the air.

When common cane-sugar is dissolved in water and mixed with yeast in a similar way, fêrmentation is induced as before. The cane-sugar is first changed into fruit-sugar by the action of the yeast, and then the fruit-sugar is split up into alcohol and carbonic acid. These changes take place in close as well as in open vessels, so that the presence of air is in no way necessary to their perfect and rapid completion.

If starch be converted into grape-sugar by the action of diluted sulphuric acid, or of a mixture of malt, as described in a preceding chapter,[2] and yeast be then added to the sweet solution, the same changes and the same production of alcohol take place. From potato-starch, treated in this way, large quantities of spirit (potato-brandy) are manufactured in France, Germany, and the northern countries of Europe.

But by a still more beautiful process the starch of barley and other grains is converted into grape-sugar before it is removed from the seed, and is then split up as before, by means of yeast, into alcohol, water, and carbonic acid.

In a previous chapter[3] it has been shown that these grains consist essentially of two principal substances—starch and

[1] This splitting up takes place as follows:—

Let C denote 12 parts by weight or 1 atom of carbon, H 1 part or 1 atom of hydrogen, and O 16 parts or 1 atom of oxygen—

		C	H	O
Then *one* of grape-sugar, ...	=	6	12	6
Two of alcohol, ...	=	4	12	2
Two of carbonic acid, ...	=	2	0	4
And these together make		6	12	6

So that the substance of one of grape-sugar is split up into two of alcohol and two of carbonic acid. This splitting up is induced by the yeast, which, however, affords none of the materials of which the alcohol, &c., consist.

[2] See "The Sweets we Extract," p. 181.

[3] See "The Bread we Eat," p. 69.

gluten. When moistened, in favourable circumstances, the grain begins to sprout. The starch and gluten it contains are, of course, intended to form the first food of the young plant; but these substances are insoluble in water, and therefore cannot, in their natural state, pass onwards from the body of the seed to supply the wants of the growing germ. It has been beautifully provided, therefore, that both of them should undergo chemical changes as the sprouting proceeds. This takes place at the base of the germ—exactly where and when they are wanted for food. The gluten is changed, among other products, into a white soluble substance, which has been distinguished by the name of *diastase*, and the starch into soluble grape-sugar. Hence the sweetness of sprouted corn.

Starch can be transformed into sugar, as I have explained (p. 181), by the agency of a minute quantity of sulphuric acid. It is so transformed also by this diastase. Produced in the sprouting seed in contact with the starch, the diastase changes the latter into soluble starch, dextrine, or sugar, and makes it soluble in the sap just as it is required. By this means the infant plant is fed.

The maltster, brewer, and distiller avail themselves of this natural change in the constituents of sprouting grain, and on a large scale call into action the remarkable chemical influence of this unorganised ferment known as diastase. This is abundantly illustrated by the chemical history of the art of brewing.

1°. Malt-Beers are so called because they are prepared, either in whole or in part, from infusions of malted barley. The manufacture of these drinks involves two distinct chemical processes: *first*, the change of the starch of the grain into sugar; and *secondly*, the change of the sugar into spirit-of-wine or alcohol. With a view to the first of these ends, the grain is manufactured into malt; to attain the second, it is submitted to fermentation through the medium of yeast.

a. The Malt.—The maltster first puts his barley into the cistern, where it remains fifty hours. It is then shifted to the "couch," and twenty hours afterwards is removed to the floors. When, after ten or fourteen days, the young rootlet has attained some length, the further growth is arrested by drying the grain gently on the floor of the kiln. It is now malted barley,

and has a sweet taste, showing that it already contains sugar. Other grains—such as wheat, oats, and rye—may be converted into malt by a similar process. Even Indian corn is malted in North America; and in South America this malt has been used for making beer from the remotest times. In Europe, however, barley has been found by long experience to be best adapted for this process—though malted rye and wheat are employed along with the barley for the manufacture of some particular kinds of beer. In point of fact, although malt makes the best beer, all starchy grains are capable of furnishing beer if they do not contain noxious principles, and are fermented. Much beer is now made wholly or partly from glucose, obtained by submitting starch to the action of sulphuric acid. Such beer is deficient in the aromatic principle found in the skin of the grain. The total quantity of sugar used in breweries in the United Kingdom in 1877 was over 90 millions of pounds. The artificially prepared sugar, made from starch, paper, &c., by the action of sulphuric acid, is also largely used for brewing. The imports of this substance have increased from 8508 cwt. in 1867 to 221,495 cwt. in 1876.

b. The Beer.—The brewer or distiller bruises the malt (which has been previously screened or sifted from the rootlets or *acrospires*), and introduces it into his mash-tun, with water gently warmed to 157° or 160° Fahr. This water dissolves first the sugar which has already been formed in the seed, and afterwards the diastase. This latter substance then acts upon the rest of the starch of the seed, converting it first into soluble starch, then into dextrine, a species of soluble gum, and finally in great part into grape-sugar. If the process has been well conducted, little but the husk of the grain is left undissolved, and the liquor or wort has a decidedly sweet taste.

Three circumstances are remarkable in regard to this diastase. *First,* That even in good malt, about 1 lb. of diastase only is formed for every 100 parts of starch contained in the grain. *Secondly,* That this 1 lb. of diastase is sufficient to change 1000 lb. of starch into grape-sugar. And *thirdly,* That by heating the solution containing it to the boiling-point, the diastase is killed, as it were: its power of changing starch into sugar is wholly destroyed.

The first and second of these circumstances enable the brewer, if he choose, to mix with his malt a certain portion of starch, or of unmalted grain. The diastase of the malted portion is sufficient to transform into sugar, not only the whole starch of the malt, but all the starch also of the raw grain. Thus both the expense and the waste which would attend the malting of the latter is avoided. In this country the brewer is not permitted to avail himself of this opportunity of adding raw grain. Continental brewers, however, and our home-distillers, both practise it largely.

The third circumstance determines the time when the wort may be safely boiled—which is the next stage in the manufacture of beer. The change of all the starch into sugar or dextrine being effected, the diastase is no longer of service, and the wort may be heated to boiling, with advantage. By this higher temperature the action of the diastase is stopped, and at the same time the albumen which the water has dissolved out of the grain is coagulated and separated in flocks. Advantage is taken also of this boiling to introduce the hops; and these, besides imparting their peculiar bitterness and aroma to the liquid, help further to clarify it, their tannin curdling most of the remaining albuminous matter in the liquor. Both the length of the boiling and the quantity of hops added to the liquid vary with its richness in sugar, and with the quality of the beer it is intended to make.

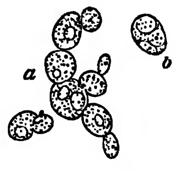
The boiled liquor is run off into shallow vessels, and cooled as rapidly as possible to the best fermenting temperature, which lies between 54° and 64° Fahr. when "top yeast" is employed, but is much lower for "bottom yeast," used in brewing the light beer of Bavaria. It is then transferred to the fermenting tun; a sufficient quantity of yeast is added—obtained, if possible, from a kind of beer different to that which it is desired to make—and it is allowed to ferment slowly for six or eight days. During this fermentation, the sugar of the wort is split up into the alcohol which remains in the beer, and into the carbonic acid gas which, for the most part, escapes from the surface of the liquid and mingles with the surrounding air. Cane-sugar assimilates water during fermentation, becomes converted into grape or fruit sugar, and then splits up into alcohol and carbonic acid gas.

Three things are notable in this process: *first*, that the

quantity of yeast which is added, and the temperature at which the liquor is afterwards kept to ferment, vary with every kind of beer; *secondly*, that the yeast works better when transferred occasionally from one sort of beer to another; and *thirdly*, that the whole of the dextrine and sugar contained in the wort is never in practice transformed into alcohol. Good beer—however clear, hard, bright, and bitter—always retains a pleasant, sweetish taste. From one-half to three-fourths only of the fermentable substances in the wort is decomposed. Were the fermentation not so regulated as to leave this residue of undecomposed dextrine, the beer would refuse to keep. It would turn sour in the cask.

I do not follow further the manufacture of this important beverage. But I cannot dismiss the beautiful series of operations of which it consists, without calling the attention of my reader for a moment to the remarkable place which the minute yeast-plant (fig. 39), occupies among the agents by which the final result is attained. I have already described this plant; how small it is—how mysteriously it appears, and how rapidly it grows (p. 62).

Fig. 39.



Yeast-plant. *a*, Row of cells, from "top yeast;" *b*, Single cell with young cells inside, as grown on moist plaster.

As sulphuric acid and diastase, by mere contact apparently with starch, convert it wholly into sugar; so yeast, by a similar species of contact, converts the sugar wholly into alcohol and carbonic acid. How either of these transformations is effected by the agents employed, we cannot explain.

There is this interesting difference in the way in which these three agents operate—that, while the sulphuric acid employed to transform starch into sugar remains unchanged in quantity, and while the diastase itself changes and disappears, the yeast lives, multiplies, grows, increases in quantity, and augments in size and vegetable development. The minuteness of the yeast-plant, consisting in its simplest form of only a single cell, long prevented it from being generally regarded as a form of living matter. But the changes it undergoes in the fermenting tub day by day, as shown by the microscope, prove it to be unquestionably a growing vegetable. The increase in the quantity of yeast during fermen-

tation is so great, that 35 lb. of dry yeast, employed in brewing 1250 gallons of beer, have been known to increase to, or yield, 247 lb.

But that the yeast lives and increases in the fermenting liquid, does not explain its action upon the sugar. The mystery remains none the less. How this plant, in growing rapidly itself, should induce the sugar at the same time to split itself up as I have described, and that without combining with or otherwise appropriating any of the new substances produced — this is still altogether inexplicable. Neither chemistry nor physiology can as yet hazard even a plausible, light-bringing conjecture upon the subject. It is something to be able to see, in regard to any point that we have reached, the actual limits of our positive knowledge. It has, however, been ascertained that an active ferment may be dissolved out of the yeast-cells.

The composition of the beer, obtained as I have described, varies with almost every sample.

a. When beer is evaporated or boiled to dryness, it leaves behind a certain quantity of solid matter, usually spoken of as malt-extract. This consists of undecomposed sugar, of soluble gluten from the grain, of bitter substances derived from the hop, of glycerine, and of a certain proportion of mineral matter. It varies in quantity from less than 4 to upwards of 8 lb. in every 100 lb. of good beer. In fine wine-like beers, such as our modern English bitter beers, the quantity of extract is small. In heavy sweet beers, it is large. Good Edinburgh ale contains about 4 per cent, or nearly half a pound to the gallon. The German Brunswick beers are remarkable in this respect. A sweet small-beer of that city contains 14 per cent of extract; and a scarcely half-fermented black drink, called Brunswick *mumme*, as much as 39 per cent—about 5 lb. to the gallon. The nutritive qualities of beer, which are often considerable, depend very much upon the amount and nature of this extract.

b. But beer contains alcohol also, the result of the fermentation; and this varies in quantity quite as much as the extract. Thus—

	Of alcohol.
Small beer contains .	1 to 1½ per cent by weight.
Porter, . . .	3½ to 5½ „ „
Brown stout, . .	5½ to 6½ „ „
Bitter and strong ales, .	5½ to 10 „

By measure, these proportions of alcohol are about one-fourth more than the numbers above given.

Upon this alcohol depends the purely intoxicating effect of malt-liquors. And in this respect our strong ales have about the same strength and influence as hock and the light French wines. But they contain, in addition, and as distinguishing them from the wines—

First, The nutritive matters of the extract which are derived from the grain. These, as I have said, vary from 4 to 8 per cent. In milk, the model food, the nutritive matter amounts to 12 or 13 per cent, and is, besides, somewhat richer in curd, the ingredient which corresponds to the gluten of the plants. Beer, therefore, is food as well as drink. A little beef eaten with it makes up the deficiency in gluten, as compared with milk; so that beef, beer, and bread—our characteristic English diet—are most philosophically put together, at once to strengthen, to sustain, and to stimulate the bodily powers.

Secondly, The bitter narcotic principle of the hop. By this, not less than by its nutritive quality, beer is distinguished from wine. Of this ingredient and its effects I shall treat in a subsequent chapter.[1]

We may set down the main constituents of beer in the following statement:—

1. Alcohol, or spirits of wine, 8 to 3 per cent.
2. Dextrine and glycerine, about 4.5 per cent.
3. Sugar, about 0.5 per cent.
4. Hop-resin, oil, &c., about 0.5 per cent.
5. Gluten, about 0.5 per cent.
6. Acetic, lactic, and succinic acids, about 0.3 per cent.
7. Carbonic acid gas, about 0.15 per cent.
8. Mineral matter, about 0.3 per cent.

2°. Chica, or Maize-Beer.—The use of malt-beer in Germany, and probably also in England,[2] is very ancient; but that of chica or maize-beer in South America appears to be equally remote. It was a common drink of the Indians long before the Spanish conquest.

[1] See "The Narcotics we Indulge in."

[2] Eumenes, in his panegyric upon Constantius, in the year 296, remarks, that Britain produced such abundance of corn that it sufficed to supply not only bread but a drink comparable to wine. And in 694, Ina, king of the West Saxons, ordered every possessor of ten hides of land to pay him 12 ambers (nearly 90 wine gallons) of Welsh ale.

The usual way of preparing chica is to water or moisten Indian corn, as the English maltster does his barley—to leave it till it sprouts sufficiently, and then to dry it in the sun. It is now maize-malt. This malt is crushed, mashed in warm water, and then allowed to stand till fermentation takes place. The liquor is of a dark-yellow colour, and has an agreeable, slightly bitter, acid taste.[1] It is in universal demand throughout the west coast of South America, and is consumed in vast quantities by the mountain Indians. Scarcely a single hut in the interior is without its jar of the favourite liquor.

Posole is another maize-drink, which, in Yucatan and Tabusco, forms a chief article of food. It is prepared by steeping the grain for a length of time in water, along with a little lime, grinding the steeped grain, and then mixing the mass with water. It is taken cold, a little sugar being often added to it.

In the valleys of the Sierra, however, the most highly-prized chica is made in a somewhat different manner. "All the members of the family, including such strangers as choose to assist in the operation, seat themselves on the floor in a circle, in the centre of which is a large calabash, surrounded by a heap of dried maize (malt). Each person takes up a handful of the grain and thoroughly chews it. This is deposited in the calabash, and another handful is immediately subjected to the same process, the jaws of the company being kept continually busy until the whole heap of corn is reduced to a mass of pulp. This, with some minor ingredient, is mashed in hot water, and the liquid poured into jars, where it is left to ferment. In a short time it is ready for use. Occasionally, however, the jars are buried in the ground, and allowed to remain there until the liquor acquires, from age, a considerable strength, and powerfully intoxicating qualities. Chica thus prepared is called *chica mascada*, or chewed chica, and is considered far superior to that prepared from maize crushed in the usual manner. The Serrano believes he cannot offer his guest a greater luxury than a draught of old chica mascada, the ingredients of which have been ground between his own teeth."[2]

Disgusting as this process of manufacture appears to the

[1] Von Tchudi—Travels in Peru, p. 151.
[2] The Leisure Hour, June 1853, p. 372.

European, it is nevertheless founded in reason, and presents a sort of instinctive or experience-born application of a beautiful chemico-physiological principle.

We have seen that grain is malted in order that diastase may be produced, and that it is then bruised and digested in warm water, in order that this diastase may convert the starch into sugar. But the saliva of the mouth possesses a similar property of converting starch into sugar. Mix starch intimately with saliva, and keep the mixture moderately warm for a time, and sugar will gradually be produced. This is what the. Indian does in preparing his chica mascada. He chews the grain thoroughly: this reduces it to a fine pulp, and at the same time mixes it intimately with saliva. When set aside, this pulp sweetens and afterwards ferments.

The maize he makes his liquor from is a large grain. The diastase produced during the malting—which is not always well conducted—is often insufficient to convert the whole of the starch into sugar, but the mixture of saliva aids the diastase, and insures the change. It also aids in producing and promoting the fermentation which succeeds. It is very interesting to discover so beautiful a chemico-physiological reason for a practice so disagreeable and apparently so unaccountable.

Chica is not always made from maize. It is prepared also from barley, rice, pease, yuccas, pine-apples, grapes, and even bread—(Von Tschudi). The name, originally restricted to the liquor obtained from maize, appears to have been gradually applied to the fermented drinks of various kinds which are in use in different parts of South America. A variety of chica mascada is made in some places from the pods of the *Prosopis algaroba*, which are very sweet, mixed with the bitter stalks of the *Schinus molle*. Old women are employed to chew these pods and stalks. The chewed pulp is mixed with water, and the mixture soon ferments and forms an intoxicating beer.[1] The addition of the bitter ingredient in this case is interesting, not only because it resembles our own more recent practice of adding hops and other bitters to our beer, but because it intimates the existence of a remarkable similarity in natural taste among tribes of men most remote in situation, and most unlike in understanding and habits. Maize-beer is also

[1] Chemical Gazette, 1844, p. 131, note.

in use among the natives of Angola. The grain is steeped in water, then kept in heaps till it has sprouted, and is finally ground and then boiled with the starchy preparation of the mandioc root. This African beer is known as *garapa* or *uallua*.

3. BOUZA, MURWA, or MILLET-BEER, is a favourite drink of the Crim Tartars. They prepare it from fermented millet-seed, to which they add certain admixtures which render it excessively astringent—(OLIPHANT.[1]) They call it *bouza*.

The Arabians, Abyssinians, and many African tribes, give the same name to a fermented drink which they usually prepare from *teff*, the seeds of the *Poa abyssinica*. They occasionally employ millet-seed, however, and even barley, for the purpose. Their bouza is described as a sour, thick drink.

In Sikkim, on the southern slopes of the lower Himalaya, millet-beer, under the name of *murwa*, is in very general use. It is prepared by moistening the grain of a kind of millet (*Eleusine coracana*), and allowing it to ferment for some days. On a portion of this, considered sufficient for the occasion, or for the day's consumption, hot water is then poured. It is usually drunk while still warm—is served in bamboo jugs, and sucked through a reed. When quite fresh, it tastes "like negus of Cape sherry, rather sour." It is very weak, but in a hot day's march is described as a very grateful beverage—(HOOKER).[2] The beer of the Kafirs is prepared from a kind of millet, the grain of which is allowed to ferment by keeping it in a warm place covered with wet mats. When thus malted it is artificially dried. It is then simmered in an earthen pot, and afterwards set aside to ferment in a warm sunny place. After skimming it becomes the drink called *uchwala*, a sort of spirituous gruel of a very fattening character. It is only when consumed in immense quantities that it has an intoxicating character; but the Kafir chiefs do sometimes imbibe so much as to lose their usual staid demeanour. Uchwala is kept in marvellous vessels of plaited grasses, quite watertight, and lavishly ornamented. In fact the delight of the Kafir in this drink has stimulated his inventive faculties to an unusual degree.

[1] Russian Shores of the Black Sea, p. 277.
[2] Himalayan Journals, vol. i. pp. 285, 291.

With the chemical peculiarities of these different forms of millet-beer we are at present unacquainted. The speciality in their preparation seems generally to be, that they are fermented in the grain, and not in the wort, as is the case with European beers; and that the fermentation is spontaneous, and not produced by yeast. Under these circumstances, three chemical changes will be proceeding in the moist grain at the same time:—

First, The starch of the grain will be transformed into sugar by the agency of the diastase, which is formed during the sprouting that ensues after the grain is moistened.

Secondly, This sugar is partly changed into alcohol by the fermentation which spontaneously commences.

Thirdly, A part of the sugar is changed also into lactic acid, or the acid of milk, through the action of the gluten of the millet, which, during the spontaneous fermentation, possesses the peculiar property of producing this change.

The drink obtained by infusing this altered grain in water agrees with our European malt-liquors, therefore, in containing nutritive matters derived from the starch and gluten of the grain. But it differs from them in containing lactic instead of acetic acid. The Indian murwa differs from them also in being drunk like tea soon after it is infused, and in containing no bitter addition resembling our hop. The astringency of the bouza of the Crim Tartars seems to indicate that *they* use something in preparing it besides the fermented millet-seed.

It is a singular coincidence that the mode of infusing in hot water and sucking through a tube, practised on the Himalayas, is exactly the same as is practised in South America in preparing maté or Paraguay tea. In each of these remote districts the beverage prepared is taken hot, and is in universal use; and yet, so far as I am aware, this mode of drinking is adopted only in North-eastern Asia and in Southern America. Is there anything more than a mere coincidence in this?

4°. Quass, or Rye-Beer, a favourite Russian drink, is a sharp, acid, often muddy liquor, which, in taste and appearance, resembles some of the varieties of bouza. It is made by mixing rye-flour, and occasionally barley-flour, with water, and fermenting. It may possibly contain lactic acid.

Rye-beer affords an instance in which unmalted grain is employed in the manufacture of beer on the continent of Europe.

5°. KOUMISS, or MILK-BEER.—Milk, as I have explained in the preceding chapter, contains a peculiar kind of sugar, less sweet than cane-sugar, to which the name of milk-sugar is given. This sugar, when dissolved in water, does not ferment upon the addition of yeast; but when dissolved in the milk, along with the curd and butter, it readily ferments, is transformed into alcohol and carbonic acid, and gives to the liquor an intoxicating quality.[1] This fermentation will take place spontaneously, but it is hastened by the addition of yeast or of a little already fermented milk. The fermented liquid is the *koumiss* of the Tartars. Mare's milk is richer in sugar than that of the cow, and is usually employed for the manufacture of milk-beer. It is prepared in the following manner:—

To the new milk, diluted with "a sixth of its bulk of water, a quantity of rennet, or, what is better, a sour koumiss, is added, and the whole is covered up in a warm place for twenty-four hours. It is then stirred or churned together till the curd and whey are intimately mixed, and is again

[1] This transformation is effected, through the agency of the curd, in a way not yet clearly understood. The mere change of substance—that is, of the sugar into alcohol and carbonic acid, supposing it to be produced directly—appears very simple. Thus, C representing carbon, H hydrogen, and O oxygen:—

		C	H	O
One of milk-sugar in crystals is . . .	=	12	24	12
Four of alcohol are	=	8	24	4
Four of carbonic acid, ...	=	4	0	8
Sum, ...		12	24	12

So that in one of milk-sugar there are exactly the materials to form four of alcohol and four of carbonic acid. But the transformation is probably much more indirect and circuitous—the curd changing one portion of the sugar into lactic acid, this acid changing the rest of the milk-sugar into grape-sugar, and then the altered curd again, in some unknown way, causing this grape-sugar to ferment and split up into alcohol and carbonic acid. The non-chemical reader will understand in some degree, from this example, how difficult it is to follow, and distinctly make out, the rapid and successive changes which often take place in consequence of the mutual reactions of different chemical substances.

left at rest for twenty-four hours. At the end of this time it is put into a tall vessel and agitated till it becomes perfectly homogeneous. It has now an agreeable sourish taste, and, in a cool place, may be preserved for several months in close vessels. It is always shaken up before it is drunk. This liquor, from the cheese and butter it contains, is a nourishing as well as an exhilarating drink, and its consumption is not followed by the usual bad effects of intoxicating liquors. It is even recommended as a wholesome article of diet in cases of dyspepsia or of general debility."

By distillation, ardent spirits are obtained from this koumiss, and, when carefully made, a pint of the liquor will yield half an ounce of spirit. To this milk-brandy, when only once distilled, the Kalmucks give the name of *arraca*, and from the residue in the still they make a kind of hasty-pudding.

The Arabians and Turks prepare a fermented liquor, or milk-beer, similar to the koumiss, which the former call *leban* and the latter *yaourt*. In the Orkney Islands, and in some parts of Ireland and of the north of Scotland, buttermilk is sometimes kept till it undergoes the vinous fermentation and acquires intoxicating qualities.

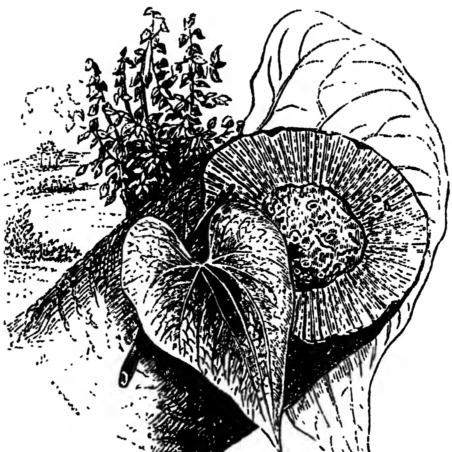
This milk-beer agrees with the malt-beers in containing a considerable proportion of nutritive matter. The butter and cheese of the milk remain as nutritious ingredients of the beer. It differs from the malt-beers in containing more acid, and in owing its sourness not to acetic acid but to the peculiar acid of milk, the lactic acid which is present in malt-beer in very small quantity. In both these respects it agrees remarkably with millet-beer. We shall see in the next chapter that, in the kind of acid it contains, milk-beer agrees also with cider.

6°. Ava, Cava, or Arva.—Similar to chica in the mode of preparation is the ava or cava of the South Sea Islands. This liquor is in use over a very wide area of the Pacific Ocean, and among the inhabitants of very remote islands. In Tahiti, the use of it is said to have swept off many of the inhabitants. In the Sandwich Islands it was some years ago forbidden—(Simpson). In the Samoan group it is the only intoxicating liquor known, and old and young, male and female, are very fond of it—(Wilkes). In the Tonga Islands it is prepared and drunk on every festive occasion—(Mariner).

And in the Fiji Islands, the preparation of the morning drink of this liquor for the king was one of the most solemn and important duties of his courtly attendants—(WILKES).

The name of ava is given to the root of the intoxicating long-pepper (*Macropiper methysticum*), fig. 40, which is chewed, either in the fresh or in the dried state, as the Indian chews his maize. The pulp is then mixed with cold water, which, after a brief interval, is strained from the chewed fibre, and is ready for use. The taste, to one unaccustomed to it, is not pleasant. It reminded Captain Wilkes of the taste of rhubarb and magnesia!

Fig. 40.



Macropiper methysticum—The Ava Pepper shrub.
Scale, 1 inch to 3 feet.
Leaf, 1 inch to 2 inches. Outline of leaf, natural size.
Part of stem and root, showing section, natural size.

According to the white persons who have tried it, this infusion does not intoxicate in the same manner as ardent spirits. It more resembles opium in some of its effects, producing a kind of temporary paralysis, tremors, indistinctness, and distortion of vision, and a confused feeling about the head.

The presence of a narcotic ingredient in the root of this

plant is very probable. Its leaf is used very largely for chewing with the well-known betel-nut,[1] and is believed to have a share in producing the pleasing state of mild excitement in which the betel-chewer delights. The extraction of this narcotic substance, during the process of mastication and straining, accounts for the intoxicating property acquired by the liquor, before ordinary fermentation and the production of common alcohol has had time to begin. Still, that the saliva produces a chemical change in the ingredients of the root, upon which change their intoxicating quality in some measure depends, is in itself very probable, from what we know of the general properties of saliva. And the probability of such a change becomes greater, when it is considered that the intoxicating qualities of the leaf only become sensible to the betel-chewer as the roll he chews becomes softened in his mouth, and saturated with saliva.

In the Tonga Islands, the ava-root, when dry, is split up into small pieces with an axe or other sharp instrument, is scraped clean, and is then handed to the attendants to be chewed. No one offers to chew it but young persons who have good teeth, clean mouths, and have no colds. The women often assist—(MARINER). But as the most curious passage I have met with in connection with the preparation and use of this liquor, I quote the following from Captain Wilkes:—

"The ceremony attending the ava-drinking of the king at Somu-somu, one of the Fiji Islands, is peculiar. Early in the morning, the first thing heard is the king's herald, or orator, crying out in front of his house, 'Yango-na ei ava,' somewhat like the muezzin in Turkey, though not from the house-top. To this the people answer, from all parts of the koro, 'Mama' (prepare ava). The principal men and chiefs immediately assemble together from all quarters, bringing their ava-bowl and ava-root to the mbure, where they seat themselves to talanoa, or converse on the affairs of the day, while the younger proceed to prepare the ava. Those who prepare the ava are required to have clean and undecayed teeth, and are not allowed to swallow any of the juice, on pain of punishment. As soon as the ava-root is chewed, it is thrown into the ava-bowl, where water is poured upon it with great for-

[1] See "The Narcotics we Indulge in."

mality. The king's herald, with a peculiar drawling whine, then cries, 'Sevu-rui-a-na' (make the offering). After this a considerable time is spent in straining the ava through cocoanut husks; and when this is done, the herald repeats, with still more ceremony, his command, 'Sevu-rui-a-na.' When he has chanted it several times, the other chiefs join him, and they all sing, 'Mana endina sendina le.' A person is then commanded to get up and take the king his ava, after which the singing again goes on. The orator then invokes their principal god, Tava-Sava, and they repeat the names of their departed friends, asking them to watch over and be gracious to them. They then pray for rain, for the life of the king, the arrival of wangara papalangi (foreign ships), that they may have riches, and live to enjoy them. This prayer is followed by a most earnest response, 'Mana endina' (amen, amen). They then repeat several times, 'Mana endina sendina le.' Every time this is repeated, they raise their voices until they reach the highest pitch, and conclude with 'O-ya-ye!' which they utter in a tone resembling a horrid scream. This screech goes the rounds, being repeated by all the people of the koro, until it reaches its farthest limits, and, when it ceases, the king drinks his ava. All the chiefs clap their hands with great regularity while he is drinking; and after he has finished his ava, the chiefs drink theirs without any more ceremony. The business of the day is then begun. The people never do anything in the morning before the king has drunk his ava. Even a foreigner will not venture to work or make a noise before that ceremony is over, or during the preparation of it, if he wishes to be on good terms with the king and people."[1]

It will strike the reader as a singular circumstance, that this mode of preparing fermented drinks — the ava and the chica — by chewing the raw materials, should exist in the islands of the Pacific, and amid the sierras of South America, and there only. The materials employed in the two regions are very different, and the chemical changes produced by the chewing in the two cases very different also, though the apparent result, in the production of an intoxicating liquor, is the same. Where did the custom originate? Is its origin continental or insular? Is it in any way con-

[1] Wilkes's United States' Exploring Expedition, vol. ii. p. 97.

nected with the eastward migrations, which the unknown past has doubtless witnessed, towards the Pacific shores of the American continent? Where analogies of tongue and features fail, may not the occurrence of strange customs point to old national relations which now no longer subsist?

7°. SAKÉ, or RICE-BEER.—The chief native fermented liquor of Japan goes by the general name of *saké.* It is a rice-beer or wine. Professor R. W. Atkinson of the University of Tokiô, has described[1] from personal inspection the process of manufacturing this beer. It is curious, for several reasons, amongst which we include the fact that the natural ferment produced in the germinating rice seems to be neglected as a means of securing the necessary chemical changes whereby the starch of the grain is transformed into the alcohol of the beer. The first step in saké-brewing is the preparation of a special ferment, made by sowing the spores of a fungus upon steamed rice, which has been previously mixed with some wood or plant ashes, and keeping the whole at a high temperature for ten days. A green fungus, full of spores, is then formed upon the rice-grains. These spores are used for producing the actual yeast, being sown for that purpose on steamed rice, and kept a few days. The spores grow, producing fine, white, silky threads of *mycelium*, which, when mixed with steamed rice and water, and stirred for about ten days, and subsequently heated to 95° Fahr. for eight to thirteen days longer, by means of hot water, causes the change of the starch into sugar. At least, such appears to be the case, although it is possible that another fungus or some unorganised ferment may be the real cause of the change, the ordinary yeast-plant abounding in the later stage of the process. All the above processes having had for their object nothing but the preparation of this yeast, the actual fermentation of the rice-liquor now proceeds, and is continued till the finished and clarified product, which has a yellow colour, contains from 12 to 15 per cent of alcohol. It is generally served warm, in melon-shaped porcelain jars, which are placed in hot water till they have attained the right temperature. A common kind of saké is made for immediate consumption, containing only 5 per cent of alcohol.

There are several features in the above process which are

[1] See a paper in 'Nature,' Sept. 12, 1878.

worthy of remark, such as the production of the aerial spores of the fungus, and the fertilisation of the material used by means of vegetable ashes, which are doubtless rich in those manurial constituents, potash and phosphoric acid, in which rice itself is somewhat deficient. Moreover, this elaborate and tedious Japanese method of getting alcohol from rice-starch affords a striking contrast to the modern simple and rapid plan now so largely adopted in Europe, of attaining the same end by boiling rice with weak sulphuric acid, and then allowing the grape-sugar thus formed to ferment. Saké is remarkable for containing so high a percentage of alcohol as 15, and it has been hitherto regarded as a distilled spirit, not a mere fermented liquor. In the Japanese saké-breweries such a spirit is, according to Atkinson, also prepared.

CHAPTER XIII.

THE LIQUORS WE FERMENT.

THE WINES.

The wines.—Apple and pear wines.—Cider and perry.—Differences in quality. —Varieties of cider-apple.—Composition of cider; tendency to sour.— Grape-wines.—Rapid fermentation of grape-juice.—Circumstances influence the quality of wine.—Composition of wine.—Proportion of alcohol in different wines; proportion of sugar.—Tartaric acid the peculiar acid of grape-wine.—Proportions of acid in different wines.—Œnanthic ether gives the vinous flavour to wines.—Peculiar odoriferous principles which impart to each wine its own flavour or bouquet.—Consumption of wine in the United Kingdom.—Palm-wine or toddy.—How extracted from the cocoa-nut tree, and from the date-tree.—Extensive use of palm-wine.—Sugar-cane wine, or guarapo.—Pulque, or agave-wine.—Soma-wine of India.

II. The Wines.—Wines are distinguished from beers chiefly by these characters: *first*, they contain little of that solid nutritious matter which enables our home-brewed beer to feed the body as well as quench the thirst and exhilarate the spirits; *secondly*, they are free from any bitter or narcotic ingredient, such as the hops we add so largely to many of our English ales; *thirdly*, they are all fermented, without the addition of yeast, by a spontaneous fermentation; and *fourthly*, they contain other acids besides the acetic acid, or vinegar, to which sour beer owes nearly all its acidity.

1°. Apple and Pear Wines. — Cider and perry are well-known fermented drinks. The former especially is largely prepared and consumed in England, France, and North America.

The expressed juices of the apple and the pear contain grape-sugar already formed. When left to themselves they soon begin to ferment, without the addition of yeast; and during this fermentation, the sugar is converted into alcohol in the way already described.

Cider differs in flavour, in acidity, in strength, and consequently in quality, with many circumstances. The kinds of apples which are grown and used for the purpose, the degree of ripeness they are allowed to attain before they are gathered, the time given them to mellow or ferment before they are crushed, the skill with which the several varieties are mixed before they are put into the mill, the nature of the climate, the character of the season, the quality of the soil, the mode in which the trees are managed—all these circumstances materially affect the quality of the expressed juice as it flows from the crushing-mill; and then the after-treatment of the juice may introduce a hundred new shades of difference among the several ripe ciders produced from the same juice.

In Normandy, not less than five thousand differently-named varieties of the acid or bitter apple are known, and grown for the manufacture of cider! Some of these varieties are distinguished by as many as eighteen different names in different parts of the country. In that province also it is remarked, that the cider produced upon chalk soils, from the same varieties of apple, differs in flavour from that of sandy districts, and both from that of clay soils; so that the flavour of the soil (*goût de terrain*) is in Normandy a familiar expression in reference to the qualities of this fermented drink.[1]

Amid these differences in quality, however, there are certain general chemical characters in which all ciders agree. They are said to contain little extractive or solid nutritious matter; but this is extremely improbable. They doubtless contain albuminous substances, and it is owing to these that a slight elevation of temperature determines a rapid acetification (change into vinegar). No bitter or narcotic ingredient has been added to them. They contain, on an average, about 8 per cent of alcohol—thus resembling in strength the common hock, the weaker champagnes, and our stronger English ales. They are also chemically distinguished from malt-

[1] See the Author's Notes on North America, vol. i. p. 170.

liquors by containing lactic instead of acetic acid. In this latter respect they agree with the spontaneously-fermented bouza or murwa beer of Abyssinia and the Himalayas, and with the milk-beer of the Tartarian steppes.

Cider is further distinguished by the great facility with which it becomes sour, or runs to acid. Hence the frequency of hard cider, the difficulty of transporting it unchanged from place to place, and the frequent disappointments which attend the efforts to keep it sound for any length of time. Strong cider, without water, keeps almost as well as wine. M. Basset says he has drunk excellent cider which has been bottled ten years; and he recommends the addition of sugar as a means of giving increase of alcohol, and consequently increased power of preservation.

2°. GRAPE-WINE.—The name of wine is usually given among us, by way of eminence, to the fermented juice of the grape. This juice, like that of the apple, contains grape-sugar ready formed; and, like the juices of the apple, the pear, the gooseberry, and most other fruits, it enters easily and speedily into spontaneous fermentation. Within half an hour, in ordinary summer weather, the clearest juice of the grape begins to appear cloudy, to thicken, and to give off bubbles of gas. Fermentation has already commenced; and within three hours a distinct yellow layer of yeast has collected on the surface, and a sensible quantity of alcohol has been formed in the body of the liquid. It is still a mystery in what way the germ, seed, or sporule of the yeast-plant obtains admission into the liquid juice, and in such quantity as to give rise to an almost instantaneous fermentation.

Grape-wine differs in composition and quality with a thousand circumstances. The climate of the country, the nature of the season, the soil of the locality, the variety of grape, the mode of culture, the time of gathering, the way in which the fruit when gathered is treated and expressed, the mode of fermenting the juice or *must*, the attention bestowed upon the young wine, the manner in which it is treated and preserved, the temperature at which it is kept, the length of time it is preserved,—upon these, and numerous other conditions, the composition and quality of wine are dependent. An idea of the complexity of wine may be gathered from the fact that no less than eight different vegetable or organic acids occur

in it, not to mention the colouring matters, the glycerine, the gluten, the mineral matters, and the more important substances, namely, *alcohol*, sugar, and flavouring ethers. The above-named acids are these—

Tartaric, Malic, Tannic, Gallic,	naturally present in grape-juice or the skins.
Carbonic, Acetic, Formic, Succinic,	formed during fermentation.

All grape-wines, however, contain—

a. A notable proportion of alcohol, or pure spirit-of-wine. This proportion is different in different kinds of wine, and varies considerably also in wines of the same kind. Thus, the proportion of absolute alcohol, by weight, in our best-known wines is as follows:—

	In 100 measures.		In 100 measures.
Port,	15 to 20	Rhenish,	8 to 12
Sherry,	17 ,, 19	Moselle,	8 ,, 9
Madeira,	17 ,, 18	Malmsey,	16
Marsala,	15 ,, 17	Tokay,	9
Claret,	8 ,, 10	Champagne,	7 ,, 12
Burgundy,	8 ,, 12	Carlowitz,	11

Port, sherry, and Madeira wines, still largely drunk in this country, are therefore two or three times stronger in spirit than those of France or Germany. The wines which have the least body or spirit bear transport worst, and do not keep well, soon becoming sour from acetic acid on exposure to the air.

b. A more or less sensible quantity of grape-sugar, which has escaped the decomposing action of the fermentation. This gives to wines their sweet taste and *fruity* character. Wines are called *dry* when they contain little sugar. The order of sweetness in certain wines, as they are brought to the English market, is as follows:—

Claret, Burgundy, Rhine, Moselle, and Carlowitz contain no sugar, or a mere trace.

Sherry	contains	about	2	parts	in 100	of wine.
Madeira	,,	,,	$2\frac{1}{2}$	,,	,,	,,
Port	,,	,,	4	,,	,,	,,
Champagne	,,	,,	7	,,	,,	,,
Patras	,,	,,	15	,,	,,	,,
Lachrymæ Christi	,,	,,	27	,,	,,	,,

The extreme fruitiness of some port wines is indicated by the large proportion of sugar which this variety of wine sometimes contains. Sugar is added to the juice of the champagne grape by the grower. This is necessary, not only to give it body, but to keep it sparkling, and to prevent its becoming sour. And it is remarkable that the selection of the kind of sugar which is added has great influence upon the flavour of the wine. If doubly refined cane and beet sugars be added respectively to the same champagne, the one will give the liquor the aroma and pleasant flavour of the cane-juice, the other the disagreeable *goût* of the beet-root. In the wine, the senses of taste and smell readily discover traces of impurity derived from the sugar, which neither eye, nose, nor mouth can detect in the purified sugar itself.

c. A variable proportion of free acid, which imparts to them a more or less distinctly sour taste. We have seen that neither malt-beer nor cider is ever quite free from acid, and the same is the case with wine. Only the grape-wine is made sour by tartaric acid.[1] Thus—

Acetic acid (vinegar) is the acid of *malt-beer*.
Lactic acid is the acid of *millet-beer, milk-beer, and cider*.
Tartaric acid is the acid of *grape-wine*.
Oxalic, malic, and *citric acid* are found in English fruit-wines.

In all the four liquors, acetic acid is present in greater or less quantity, as this is always produced when the fermentation of alcoholic liquors is allowed to proceed too far. But lactic acid is found neither in malt-beer, nor in grape-wine, in sensible quantity; nor is tartaric acid found in beer or cider. These acids, therefore, characterise the liquors in which they especially exist, and establish a marked chemical distinction among the four classes of fermented drinks to which they severally belong.

Wines made from unripe grapes sometimes contain another peculiar acid which resembles the acid of lemons (citric acid), but this acid disappears from the fruit as it ripens.

Tartaric acid exists in the juice of the grape in combina-

[1] *Tartaric acid* is the acid which gives its sourness to cream of tartar, and which we use along with soda in making artificial seidlitz powders. It is so named because it is extracted from the tartar or crust which deposits itself, on the sides of wine casks or bottles, by long standing.

tion with potash, forming what is called bi-tartrate of potash, or cream of tartar—a substance which has a well-known sour taste. When the fermented juice is left at rest, this bi-tartrate gradually separates from the liquor, and deposits itself as a crust or tartar on the sides of the casks and bottles. Hence by long keeping good wines become less acid, and every year added to their age increases, in proportion, their marketable value.

In regard to acidity, due to tartaric and other fixed acids, our common wines arrange themselves in the following order:—

Champagne is the least acid.
Port and sherry come next. Then
Burgundy,
Madeira,
Claret,
Carlowitz,
Hock and Rhine wines, and
Moselle.

d. A minute proportion of an ethereal substance to which the name of *œnanthic* ether is given, and to which grape-wines owe the agreeable vinous odour which characterises them all. When obtained in a separate state, this ether is a very fluid liquid, of a sharp, disagreeable taste, but having an odour of wine so excessively powerful as to be almost intoxicating. It does not exist in the juice of the grape, but is produced during the fermentation. It seems also to increase in quantity by keeping, as the odour of old wines is stronger than that of new wines. So powerful is the odour of this substance, however, that few wines contain more than one-forty-thousandth part of their bulk of it! Yet it is always present, can always be recognised by its smell, and is one of the general characteristics of all grape-wines.

e. Besides the general vinous flavour derived from this œnanthic ether, all wines contain one or more odoriferous, more or less fragrant, substances, to which the peculiar *bouquet* or scent of each is due. As these give the special character to the wine, they are more or less different in each variety. They are present even in more minute quantity than the œnanthic ether, and, like it, mainly consist of compounds known as ethers. But other circumstances influence the flavour of wine. Thus, casks made of the wood of the

white mulberry give a slight bouquet resembling violets to sherry that has been long kept in them.

Grape-wine is the principal fermented drink of the southern European nations. The consumption in the United Kingdom in 1853 amounted to upwards of seven millions of gallons (7,197,572); in 1857 it amounted to 7,044,636, and in 1877 to 16,942,155. This is chiefly consumed by the upper classes. In England, beer is the poor man's substitute; while in Scotland and Ireland, whisky, more or less diluted with water, takes its places. The physiological effects of wines differ according to differences in their composition. Champagne, which contains not only much sugar but more tartrate of potash than port or sherry, will soon render the urine alkaline.

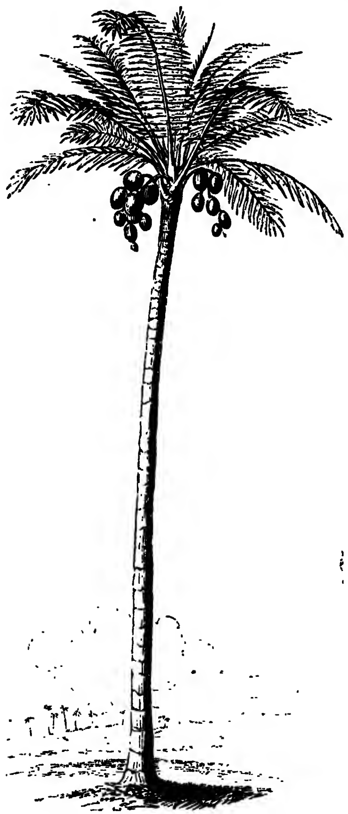
3°. Palm-Wine, or Toddy.—The sap of many palm-trees is rich in sugar. In some countries this sugar is extracted by boiling down the collected juice, as cane-sugar is extracted from the expressed juice of the sugar-cane (*see* p. 186). In other countries the juice is allowed to ferment, which it does spontaneously, and in hot climates within a very short period of time. This fermentation converts the sugar into alcohol, and the juice which contains it into an intoxicating liquor.

In the islands of the Indian Archipelago, the Moluccas, and the Philippines, an intoxicating liquor is prepared in this way from the sap of the gommuti-palm, *Saguerus saccharifer.* It is called *neva* in Sumatra, and the Batavian arrack is distilled from it. The cocoa-palm, *Cocos nucifera* (fig. 41), produces the palm-wine, known in India and the Pacific by the name of *toddy.* In Ceylon whole plantations of these palms are set apart for the extraction of this wine. The mode of collecting it in the islands of the Pacific is thus described by Captain Wilkes :—

"The karaca or toddy is procured from the spathe of the cocoa-nut tree, which is usually about four feet long and two inches in diameter. From this spathe the flower and fruit are produced; but in order to procure their favourite toddy, it is necessary to prevent nature from taking her course in bringing forth the fruit. With this view they bind up the spathe tightly with sennit, then cut off the end of the spathe and hang a cocoa-nut shell to catch the sap as it exudes. One tree will yield from two to six pints of karaca. When first

obtained from the tree it is like the milk of the young cocoa-nut, and quite limpid; but after it stands for a few hours it ferments and becomes acid. When the sap ceases to drop, another piece is cut off the spathe, and every time the flow ceases the same process is repeated until the spathe is entirely gone. Another spathe is formed soon after, above this, which is suffered to grow, and when large enough is treated in the same manner."[1]

Fig. 41.



Cocos nucifera—The Cocoa-nut Palm. Scale, 1 inch to 12 feet.

This method of cutting the spathe, or flowering head, is a very common one for procuring the sweet sap of the palm-trees. In some countries, however, it is obtained, like that of the sugar-maple and the manna-ash, by simply making an incision near the top of the tree. On the West African coast palm-juice is thus obtained from the oil-palm, *Elæis guineensis*, the cut being made in the evening, while next morning the gourd which receives the juice will be found filled with a slightly milky fluid, something like the milk in the cocoa-nut, but sweeter and richer. Collected in an old calabash it soon ferments, becoming acid and intoxicating, though its alcoholic strength is not great—(Monteiro). This custom prevails also in the interior of Africa, and in the Indian province of

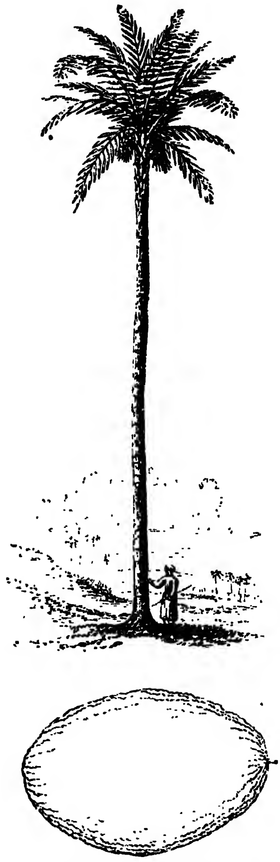
[1] United States' Exploring Expedition, vol. ii. p. 220.

Bahar, where the abundant date-palm (fig. 42) is yearly bled for the favourite toddy. Dr Hooker thus describes a grove of date-palms in which he encamped on the banks of the Soane river in that province:—

"All were curiously distorted, the trunks growing zigzag, from the practice of yearly tapping the alternate sides for toddy. The incision is made just below the crown, and slopes upwards and inwards. A vessel is hung below the wound, and the juice conducted into it by a little piece of bamboo. This operation spoils the fruit, which, though eaten, is smaller and much inferior to the African date."[1]

Date-wine was known among the Hebrews as *sechar*. In Levit. x. 9, and in Deut. xiv. 26, it is translated "strong drink."

Fig. 42.



Phœnix dactylifera.—The Date-palm.
Scale, 1 inch to 20 feet.
Fruit, 1 inch to 2 inches.

In India, generally, it is the fan-palm (*Borassus*) which is chiefly bled for toddy. But in Bahar the date-tree is preferred, because its sap more readily ferments. In the fertile oases which are sprinkled over the desert Sahara of Northern Africa, where date-tree forests cover the soil, and form the chief food and wealth of the inhabitants, this variety of palm is constantly tapped in the flowering season by the Arab and other Mohammedan tribes. They call the sap *lagmi*, and from two to three pints are yielded by each tree in a single night. But wine of the best quality is said to be yielded by the oil-palms (*Cocos butyracea*

[1] Himalayan Journals, vol. i. p. 35.

and *Elæis guineensis*) which grow on the West African coast; while for abundant yield few excel the *Caryota urens*, the most beautiful of Indian palms, which will often yield a hundred pints of toddy in the twenty-four hours!—(ROXBURGH.)

In the oasis of Tozar, a dependency of Tunis, the date-wine is to be found in every house, and reeling Arabs are frequently to be seen in the streets of its principal towns. They are strict Mohammedans; but they justify their apparent disobedience to the Prophet by saying "Lagmi is not wine, and the Prophet's prohibition refers to wine."[1]

The juice of the palm-tree varies in quality with the species of palm, and with the locality in which it is grown. As it flows from the tree it is sweet, and void of intoxicating properties; but when allowed to stand for a short time it usually ferments, and becomes first intoxicating, and afterwards acid. Upon the tendency to ferment, the place of growth appears to have an influence. This is shown by the circumstance, that while the juice of the fan-palm produces the usual toddy of India, that of the date-tree is preferred to it among the hills of Bahar, because there the sap of the fan-palm does not readily ferment—(HOOKER).

The date-juice, in the Sahara, when drunk immediately, tastes like genuine rich milk; but when allowed to stand for a night, or at most for twenty-four hours, it ferments, and, except that it continues whitish, it acquires the sparkling quality and flavour of champagne. This quality no doubt differs with the kind of tree, and with the place of growth. By distillation the fermented juice yields a strong brandy, which is almost everywhere extracted from it in Africa, as well as in Asia. At Monghyr, on the banks of the Ganges—which is celebrated not only for its iron manufactures but for its drunkenness—Dr Hooker observes that the abundance of toddy-palms was quite remarkable.

In Chili, on the American coast, wine is made from a species of palm; in India, and other parts of Asia, palm-wine is extensively consumed; while in Africa it is almost the only fermented liquor in very general use. Though we know so little of it in Europe, therefore, the wine of the palm-tree is drunk as an exhilarating liquor by a larger number of the human race than the wine of the grape.

[1] Evenings in my Tent. By the Rev. William Davis.

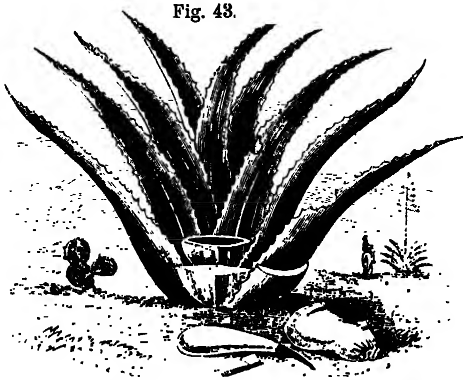
4°. Sugar-cane Wine, or Guarapo.—Like the sap of the palm-tree, that of the sugar-cane ferments spontaneously, and produces an intoxicating liquor. To this cane-wine the negroes give the name of Guarapo, and they hold it in high esteem. It contains, of course, all the ingredients of the cane-juice, except those which are changed or naturally disappear during the fermentation, and those which subside when it clarifies. In the island of Luzon (Philippines,) this liquor is called *basi*, and is very intoxicating.

5°. Pulque, Octli, or Agave-Wine, is the favourite drink of the lower classes in the central part of the table-land of Mexico, at a height of 6000 to 7000 feet above the sea. It is produced by fermenting the sap of the Maguey or American aloe (*Agave americana* or *mexicana*), which is cultivated in plantations for the purpose. This plant is of slow growth, but when full grown its leaves attain a height of five to eight feet, and even more. It flowers on an average only once in ten years, and, as in the case of palm-wine, it is from the flower-stalk that the juice is extracted. In the plantations, the Indian watches each plant as the time of its flowering approaches, and just when the central shoot or flower-stem is about to appear, he makes a deep cut, and scoops out the whole heart (*el corazon*) or middle part of the stem, leaving nothing but the outside rind. This forms a natural basin or well, about two feet in depth and one and a half in width. Into this well the sap, which was intended to feed the shoot, flows so rapidly that it is necessary to remove it twice, and sometimes three times a day. To make this more easy, the leaves on one side are cut away and the central basin laid open, as is seen in fig. 43.

The sap as it flows has a very sweet and pleasant taste like apple-must, and none of that disagreeable smell which it afterwards acquires. It is called *aguamiel* or honey-water. It ferments spontaneously, and a small quantity of old fermented juice speedily induces fermentation in that which is newly drawn, as sour leaven does in new dough. It is usual, therefore, to set aside a portion of sap, to ferment separately for ten or fifteen days, and to add a small quantity of this to each vessel of fresh juice. Fermentation is excited immediately, and in twenty-four hours it becomes pulque in the very best state for drinking. A good maguey yields from eight to

fifteen pints a-day, and this supply continues during two and often three months—(WARD).[1]

Fig. 43.



Agave americana—The American Aloe.
As prepared for producing pulque, and with a distant flowering-plant.
Scale, 1 inch to 5 feet.

The chemical changes which take place during the fermentation of this juice are the more interesting as they are in some respects peculiar.

First, Alcohol is produced as in other fermented liquors. This is shown by the slightly intoxicating qualities of the drink, and by its yielding, when distilled, an ardent spirit. To this brandy the name of *mexical* is given, or of *aguardiente de maguey*.

Secondly, An acid is formed also, or rather, as the sugar disappears, the natural acids and acidulous salts are no longer masked by the saccharine substance—the pulque, as a drink, being described as resembling cider. But,

Thirdly, The most remarkable result of the fermentation is, that the nearly smell-less juice acquires a fetid and disagreeable odour of tainted meat. This makes the liquor to be looked upon at first with disgust, especially by Europeans. It is so cool, agreeable, and refreshing, however, that this first disgust being overcome, the pulque is preferred, even by Europeans, to every other liquid.

The nature of this evil-smelling ingredient, and the chemical changes by which it is produced, have not been investi-

[1] Mexico in 1827, vol. i. p. 57.

gated. It is probably similar in kind to that which gives the bad smell to putrid fish (*trimethylamine*).[1] Substances of this kind are sometimes produced in the living plant. The Bladder-headed Saussurea, for example, which grows in the Himalayas, emits as it grows the smell of putrid meat; and the *Stapelias* are called carrion-flowers, because of the disagreeable putrid odours they exhale.

The natives of Mexico ascribe many good qualities to their national drink. It is an excellent stomachic, promotes digestion, induces sleep, and is esteemed as a remedy in many diseases. It is chiefly in the neighbourhood of large towns, like Puebla and Mexico, that the maguey plantations exist. The pulque so soon passes that state of fermentation at which it is most pleasant to drink, that the manufacture only pays where a speedy sale is certain. The brandy or aguardiente, which is not liable to this inconvenience, is largely manufactured, and more widely consumed than the pulque itself.

6°. Soma.—A kind of intoxicating beverage was formerly prepared in India from the Soma plant, *Sarcostigma brevistigma*,[2] a sacred shrub of ancient Vedic times, and still celebrated among the Brahmins. It was doubtless the first alcoholic or fermented intoxicant discovered by the Aryan race: sacred rites accompanied the drinking of the fermented sap of this plant. In the Rig Veda, enthusiastic admiration for *soma* is to be found. "The purifying Soma, like the sea, rolling its waves through my heart, has poured forth songs, and hymns, and praise." The plant became a god, the Bacchus of India.

[1] See in a subsequent chapter "The Smells we Dislike."

[2] Dr G. Birdwood—Handbook to British Indian Section: Paris Exhibition of 1878.

CHAPTER XIV.

THE LIQUORS WE FERMENT.

THE BRANDIES.

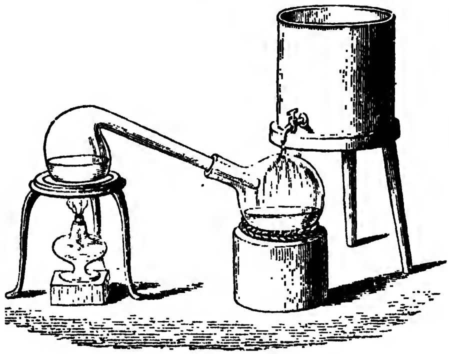
The brandies, or ardent spirits.—Methods of distillation.—Absolute alcohol. —Strength of different varieties of spirits.—Peculiarities in the preparatory processes of the distiller.—Use of raw grain mixed with malt: profit of this.—Average produce of proof-spirits.—Peculiar flavours of cognac, rum, &c.—Consumption of home-made ardent spirits in the three kingdoms. —Quantity of malt used in brewing.—Spirits consumed in the form of beer. —Comparative sobriety of England, Scotland, and Ireland.—Consumption of foreign liquors.—Alleged greater intemperance of Scotland and Ireland: how this impression has been produced.—Influence of the nutritive matter and of the hops contained in beer.—Influence of general food and temperament.—Ardent spirits serve, to a small extent, the same purpose as the starch and fat of our food, and retard the waste of the body.—Wine, "the milk of the aged."—Substances employed to give a fictitious strength to fermented liquors.

III. The Brandies, or Ardent Spirits.—When fermented liquors, such as those just described, are put into an open vessel and heated over a fire till they begin to boil, the alcohol they contain rises in the form of vapour, along with a little steam, and escapes into the air. If this boiling be performed in a close vessel, from which the vapours as they rise are conducted by a pipe into a cooled receiver, they condense again into a liquid state. This is the process called distillation, and the vessel in which it is carried on is called a still.

1°. The Distillation.—A retort connected with a receiver, over which a stream of cold water is kept flowing (fig. 44), represents the simplest form of such a still; but many more

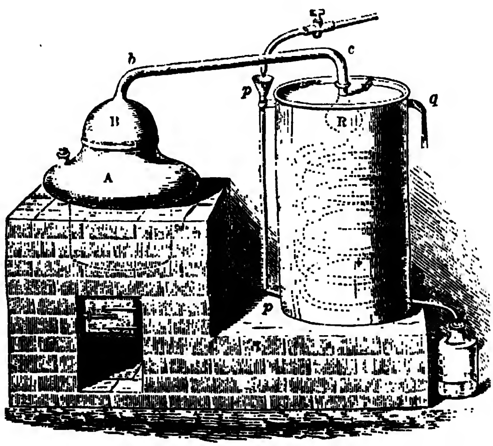
complicated forms of apparatus have been contrived for the purpose of conducting the process with economy and effici-

Fig. 44.



ency. The following illustration (fig. 45) represents a form of still, of common use in our laboratories, for distilling water. The kettle A, which contains the water, is covered by the

Fig. 45.

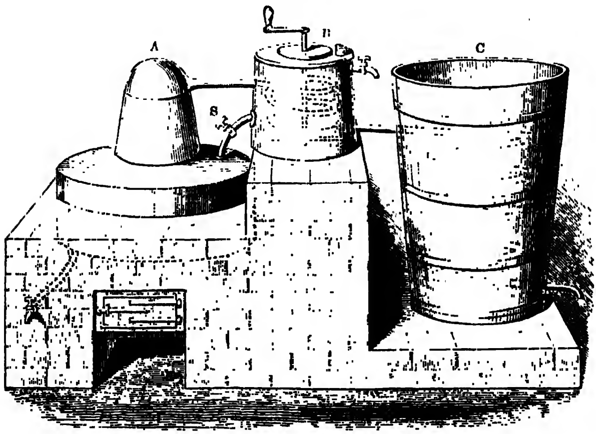


movable dome B, from which the pipe *b c* conducts the vapour into the receiver R, which is surrounded with cold water.

Thence the condensed liquid descends through a continuation of the tube, bent spirally, called the *worm*, by which it is exposed to the prolonged action of the cold water, till at length it flows quite cool into the bottle placed to receive it. Into the worm-tub a stream of cold water constantly enters by the pipe *p p*, while a similar stream of warm water as constantly escapes by the pipe *q*.

Arrangements somewhat different are made in the large distilleries, chiefly with the view of economising time and fuel. The following (fig. 46) represents a simple form of

Fig. 46.



apparatus formerly in extensive use in distilleries. The principal peculiarities in this are—*first*, The broad flat bottom of the pot or still A, by which the effect of the heat is more quickly and fully obtained; and, *secondly*, The adoption of two worms, B and C, in different vessels. In the first of these vessels cold wort is put, which is heated by the vapours as the distillation proceeds, and when hot is run at once by the stopcock S into the still. The second vessel contains cold water as before, and as this water heats it is run off, and is employed in mashing the grain. Thus heat is economised in various ways.

The spirit which passes off and condenses in the worm is more or less mixed with water; but by means of successive

distillations—or *rectifications*, as they are called—it may be obtained nearly free from water. But the last traces of moisture are removed with great difficulty. Substances having a strong attraction for water are put into the most highly rectified spirit, and then it is again distilled. In this way is obtained what chemists call absolute alcohol. This pure or absolute alcohol has a peculiar penetrating smell; a hot, fiery, and burning taste; is about one-fifth part lighter than water;[1] burns readily, but with a pale flame, when kindled in the air, and is intoxicating in a high degree. It gives off vapour freely, but it also absorbs water from the air. It is used only for chemical purposes. The spirit-of-wine, or common alcohol of the shops, which we burn in our lamps, and employ for other familiar uses, is already diluted with a considerable proportion of water, and contains, moreover, some quantity of another kind of alcohol as well as oily impurities.

In the brandies, or other varieties of ardent spirits which we consume as exhilarating drinks, the alcohol is still further diluted with water.

Thus the proportions of alcohol per cent, in some of the common varieties of commercial spirits, are as nearly follows (at 60° Fahr.):—

		Alcohol. By weight.	Alcohol. By measure.
British proof spirit contains		49	57
Commercial Cognac,	15 under proof,	41	48
Rum,	15 over proof,	58	66
Gin,	17 under proof,	40	47
Whisky,	10 over proof,	55	63

So that, on an average, we may say that the ardent spirits we consume contain less than half their weight, or three-fifths of their bulk, of absolute alcohol. They are about twice as strong as our port, sherry, and Madeira wines.

Every different fermented liquor, when distilled, yields an ardent spirit which has a flavour, and is generally distinguished by a name of its own. Thus wine yields what we call brandy or cognac; fermented molasses yields rum; Indian corn, potatoes, and rye, yield liquors which are distinguished as corn, potato, and rye brandies; while malt worts

[1] A vessel which will hold 1000 grains of water will hold only 792 of absolute alcohol. Its specific gravity is therefore said to be 792, that of water being 1000—or 0.792, that of water being 1.

or liquors give our Scotch and Irish whiskies. If juniper-berries be added previous to distillation, as is usually done in Holland, a flavour is imparted to the spirit which is characteristic of gin or Hollands ; and if the malt be dried over a peat-fire, the smell and taste of the peat (the peat-reek) accompany the spirit prepared from it; and these, in the estimation of the initiated, impart a peculiar value to peat-reek whisky.

2°. The Distillers' Processes.—But though malt and other liquors, fermented in the usual way—indeed, in almost any way—will yield brandy by distillation, yet the distiller by profession conducts his fermenting operations in a somewhat different way from the brewer, whose object is merely the production of beer. Thus—

First, We have seen that, in fermenting the wort for the manufacture of beer, a large proportion of the dextrine, and some of the sugar, is left in the liquor unchanged. The fermentation is stopped before these materials are transformed into alcohol, in order that the beer may be pleasant to drink, and that it may keep in the cask without turning sour. But the distiller's object is to obtain the largest possible quantity of spirit from his grain; he therefore prolongs the fermentation until the whole of the dextrine is changed into sugar, and all the latter, as nearly as possible, into alcohol and carbonic acid. To leave any of it unchanged would not only involve a loss of spirit, but, during the subsequent distillation, might injure the flavour and general quality of the spirit he obtained. The securing of this point, therefore, requires on his part an attention to minute circumstances, different a little in kind, but not less nice and delicate than those which determine the success of the brewer's operations.

Again, the most agreeable and generally esteemed grain-spirit is obtained when malted barley only is employed in the manufacture. This yields in Scotland and Ireland the best malt whisky. The profit of the distiller, however, is often promoted by mixing with the malt a greater or less proportion of unmalted grain, or even of potato-starch. To the reason of this I have already briefly alluded (p. 216), but it is worthy of a fuller explanation.

We have seen that it is the diastase, produced during the germination of the barley, which subsequently transforms the starch of the grain into sugar. This diastase is capable of so

transforming nearly a thousand times its own weight of starch; but good malt contains only a hundred of starch to one of diastase. The latter ingredient, therefore, will transform into sugar ten times as much starch as it is associated with in the best malt. Hence a large quantity of starch, either in the form of crushed unmalted grain, or of potato or rice starch, may be mixed even with ordinary malt in the mash-tub, with the certainty that the diastase of the malt will transform it all into sugar.

This is what the distiller does in making *grain* whisky; and the profit of it consists in this—that he saves both the expense of malting his grain and the loss of matter (usually 8 per cent)[1] which barley always undergoes in malting. He is able, also, to use for these additions of grain an inferior or cheaper material than is usually employed for conversion into malt.[2] The sweet wort obtained in this way, when fermented and distilled, yields a spirit of a somewhat harsher and less pleasant flavour than when malt alone is used.

Along with the spirit, during the distillation of fermented

[1] 100 lb. of barley yield only 80 lb. of malt. But of this loss 12 per cent consists of water driven off by the heat of the malt kiln, so that the real loss of substance is 8 lb. in the 100.

[2] Thus, in some of the Scotch distilleries, such a mixture as the following is employed :—

Malt, ...	42 bushels	at 40 lb. a bushel.
Oats, ...	25 ,,	47 ,,
Rye, ...	25 ,,	53 ,,
Barley, ...	158 ,,	53 ,,
	250	

The diastase in the 42 bushels of malt converts into sugar the starch of the whole 250 bushels, weighing eight times as much as the malt itself. This quantity of grain yields on an average 583 gallons of proof whisky, or 14 gallons from 6 bushels of the mixture.

In an Irish grain distillery the components of the mixture, or *grist*, for fermentation, were these :—

	(1.)		(2.)		(3.)	
	Bhls.	Per cent.	Bhls.	Per cent.	Bhls.	Per cent.
Malt,	280	14	240	12	80	14¼
Oats,	320	16	280	14	120	21½
Rye,	600	30	320	16	80	14¼
Barley,	800	40	920	46	280	50
Maize,	...	...	240	12	...	...
		100		100		100

liquors, there always passes over a small but variable proportion of one or more volatile oily liquids, which mix with the spirit and give it a peculiar flavour. These volatile oils vary in kind, in composition, and in sensible properties, with the source of the sugar which has been submitted to fermentation, and with the substances which are present along with it in the wort. Hence the spirit obtained from almost every different fermented liquor is distinguished by its own characteristic flavour. Thus wine-brandy, or cognac, derives its vinous flavour from the juice of the grape; and cognacs of different districts their special flavours from the kinds of wine which are distilled in each. Rum obtains its smell and taste from molasses, the scorched and altered juice of the sugar-cane; whisky, its peculiarities from the barley-malt or grain that is mixed with it; potato-brandy, from the mashed potato or its skin; palm-brandy, from the fermented toddy; the aguardiente of Mexico, from the strong-smelling pulque; and the arraca of the Kalmucks, from their fermented milk. And so with other varieties of spirit. In each case a volatile substance accompanies the spirit; and though this substance is always very small in quantity, it is yet sufficient to impart to each different variety a flavour at once characteristic and peculiar to itself. In potato-brandy the main flavouring substance is an oily liquid closely related to wine alcohol, and known as amyl alcohol; it is the chief ingredient of *fusel oil.* In beet-root spirit, and in other sorts as well, there is much amyl alcohol, generally accompanied by two other alcohols. All these bodies have more powerful poisonous properties than wine alcohol. Roughly, they may be found by pouring a little of the suspected gin or whisky on the hands, rubbing them together, and allowing the more volatile wine alcohol to evaporate. A pungent, suffocating, and nauseous odour remaining on the skin shows fusel oil, or one or more of the so-called *higher* alcohols of amyl, butyl, or propyl. These bodies, with other odorous substances found in distilled spirits from different sources, may be removed by an elaborate system of rectification, filtration through charcoal, &c.

It is chiefly from malted and raw grain of various kinds that ardent spirits are distilled in the British Islands, in northern Europe generally, and in the North American states and colonies. Maize or Indian corn is most extensively em-

ployed for this purpose in the United States, and rice and millet in China. Potatoes are used to a considerable extent on the continent of Europe, and sugar is occasionally employed in our own distilleries.

3°. Consumption of Ardent Spirits. — The manufacture and consumption of ardent spirits, especially in northern climates, is exceedingly great. In the United Kingdom, the quantity distilled and consumed, in the year ending on the 5th of January 1854, was about 25,000,000 gallons, distributed as follows :—

	Distilled.	Consumed.
England, . . .	10,729,243 gallons.	10,350,307 gallons.
Scotland, . . .	6,557,839 ,,	6,534,648 ,,
Ireland, . . .	8,136,362 ,,	8,136,362 ,,
United Kingdom,	25,423,444	25,021,317

In 1875 the quantity consumed was—

England, ...	16,737,366 gallons.
Scotland, ...	6,990,170 ,,
Ireland, ...	6,094,038 ,,
United Kingdom, ...	29,821,574

This is a very large quantity of ardent spirits to be consumed by a population of less than 34,000,000. The numbers appear especially large in the cases of Scotland and Ireland, and would seem at first sight to imply a much greater proportionate consumption of alcohol in these countries than in England.

But a simple application of chemical knowledge materially alters this first conclusion.

a. In the year ending on the 1st October 1857, and in that ending on the 31st of March 1875, the quantities of malt consumed in each of the three kingdoms, *in the making of beer*, were, in bushels, respectively—

	1857.	1875.
England, ...	33,140,696	53,661,020
Scotland, ...	1,228,520	2,840,212
Ireland, ...	2,083,968	3,221,329
United Kingdom,	36,453,184	59,722,561

From which numbers it appears, that of the 59¾ millions of bushels of malt used in the three kingdoms for the making of

beer,[1] more than 53½ millions were consumed in England alone.

Now, in the average of years, one bushel of malt yields two gallons of proof spirit, or 18 gallons of light ale or porter; so that *the malt yearly made into beer in England, if employed for making whisky, would yield the enormous quantity of* 107 *millions of gallons!*

I have already stated, however, that in the fermentation of the worts for the manufacture of beer, the whole of the dextrine and sugar is not transformed into alcohol: from one-fourth to sometimes one-half of the whole remains unchanged in the beer. The quantity of malt, therefore, which is consumed in England for the making of this milder drink does not in reality indicate the consumption of so large a number of gallons of ardent spirits as the distiller would extract from it. And we must not forget that large quantities both of beer and spirits are exported from one part of the United Kingdom to another. If we allow one-fourth of the whole for the dextrine and sugar remaining unchanged in the beer, then the quantity of alcohol or proof spirits actually consumed in the three kingdoms during 1875 would be very nearly as follows (in gallons):—

	England.	Scotland.	Ireland.
Spirits consumed as such,	16,737,366	6,990,170	6,094,038
Spirits consumed in the beer,	80,491,530	4,260,318	4,831,994
Total spirits consumed,	97,228,896	11,250,488	10,926,032

Now, if we divide these several total sums by the population of each of the three kingdoms, we obtain the following numbers for the quantity of ardent spirits consumed per head in each country:—

	England.	Scotland.	Ireland.
Total consumption in gallons,	97¼ millions.	11¼ millions.	11 millions.
Population, ...	24 ,,	3½ ,,	5½ ,,
Consumption per head in gallons,	4 1/16 ,,	3¼ ,,	2 ,,

In so far as the mere consumption of alcohol, in the form of home-made liquors, goes, therefore, it appears that Scotland does not in reality surpass England. On the contrary, England somewhat exceeds Scotland, while both England and

[1] In 1875 over 6,000,000 bushels of malt were consumed in making ardent spirits.

Scotland greatly surpass Ireland. For every head of its population, Ireland consumes less than half of what is consumed in England, and somewhat more than half of what is consumed in Scotland. This very small comparative consumption in Ireland is not to be ascribed to increased temperance caused by the labours of Father Mathew and others. On the contrary, since his time the consumption per head has greatly increased; but it is both fairer and safer, I think, to ascribe this increase to a general advance in material prosperity than to augmenting intemperance and dissipation.

b. But in estimating the actual and relative consumption of alcohol in England and Scotland, there are still two other items to be taken into calculation. Wine and foreign spirits are imported into the United Kingdom, and consumed in large quantities. Thus, in the year ending 31st March 1876, there was entered for home consumption, in gallons—

	Gallons.	Containing gallons of proof spirit.
Wine,	16,942,155	2,388,421[1]
Foreign spirits,		11,935,263
		14,323,684

Now, in England, the consumption of wine and foreign spirits, among the middle and higher classes, is certainly more general and more considerable than among the same classes in Scotland. A much larger proportion per head of the 14,000,000 gallons of spirits consumed in the form of imported liquors must therefore be ascribed to England. But the distribution of this large quantity within the United Kingdom cannot be accurately determined. However, the following figures have been arrived at after due consideration of the various data at our disposal. Of gallons of proof spirits, in one form or another, in the year 1876, there were consumed per head of the population—

	England.	Scotland.	Ireland.
In beer,	$3\frac{1}{3}$	$1\frac{1}{3}$	1
In home and foreign wines and spirits,	$1\frac{1}{3}$	$2\frac{1}{3}$	$1\frac{1}{4}$
	$4\frac{2}{3}$	$3\frac{2}{3}$	$2\frac{1}{4}$

These numbers do not, in themselves, imply very extreme intemperance in either country. Were the total quantity of

[1] Supposing foreign wines to contain an average of only ten per cent of absolute or true alcohol, which is decidedly too low.

ardent spirits we use really equally distributed and consumed in the above proportions by the whole population, cases of drunkenness would not necessarily occur. It is because many consume more than their share that the evils of intemperance so often manifest themselves.

c. Two chemico-physiological points in connection with this subject are deserving of our consideration. It is very generally believed, and has recently at least been very often asserted—and what is curious, most strongly and earnestly in Scotland itself—that in Scotland intemperance is a much more common vice than in England. But how can this be, since the average individual consumption of alcohol in England is one-fourth part greater than in Scotland?

And, again, Ireland has been reproached for its intemperance and for its love of whisky even more than Scotland, and yet the individual consumption of alcohol in any form is probably less in that island than in any northern country, either European [1] or American. Can this allegation be true, or how is it to be accounted for?

First, As to the alleged greater sobriety of England, it is to be observed that nearly three-fourths of all the alcohol drunk in that country is in the form of beer. This liquor, as we have seen, feeds and nourishes while it exhilarates the Englishman. All that the distillers' fermented wort contains, except its alcohol, remains behind in the still, and is lost as food for man. All that the brewers' wort contains, with the exception of what separates in the fining of his liquor, is retained and drunk in the beer. Sugar, dextrine or gum, glycerine, and gluten, to the amount of from 4 to 8 per cent of its weight, exist in the malt-liquor; and these, by strengthening the system, modify and mollify the apparent action of the alcohol with which they are associated. They place malt-liquors in a somewhat similar relation to ardent spirits as that which cocoa bears to tea and coffee.[2]

Besides, beer is drugged, so to speak, with hops, the tonic, narcotic, and sedative influences of which restrain, retard, and modify the intoxicating action of the spirit. Thus,—controlled by the nutritive and narcotic ingredients it is asso-

[1] In Sweden it is said that 3,000,000 of people consume 30,000,000 gallons of spirits.

[2] See "The Beverages we Infuse," p. 169.

ciated with—a larger proportion of actual alcohol or spirit will produce a smaller sensible intoxicating effect than if taken alone. But still more than all these causes is the effect produced by the greater dilution of the alcohol in beer. "Spread out the thunder into its softest tones, and it becomes a lullaby for children," says Schiller; and the same principle operates in diluting alcohol instead of drinking it *neat*. A glass of whisky diluted in a tumbler of water, and sipped so slowly that an hour passes before the whole is consumed, will have no appreciable effect upon the person who could not toss off a glass of neat whisky without intoxication. And thus a people may appear more temperate and sober, while in reality consuming a larger proportion of ardent spirits.

Secondly, But though these reasons may go far to explain the difference in the reputed sobriety of the two ends of our own island, they scarcely explain why Ireland, which consumes so little per head, should be charged with an amount of intemperance greater even than Scotland itself. Here, I believe, other causes come into play. Of these I instance only two—the less substantial food, and the more excitable temperament of the Irish people. Every one knows how easily a man becomes intoxicated if he pours down ardent spirits into an empty stomach. And from this extreme case the effect of a given quantity of spirits becomes less as the quantity of good food eaten becomes greater. It is least of all on the well-fed, muscular, beef-eating labourer.

And, again, excitable people, even when well fed, are influenced more than others by intoxicating drinks. As a people, it will, I believe, be conceded that the Irish are more excitable than the English; and likely, therefore, to be overcome by a quantity of liquor which persons of a more torpid temperament could, in the same circumstances, drink with impunity. It is probable that the quality and quantity of the national food has a material influence upon national temperament. But however this be, I am inclined to see, in the two things —in the national food and the national temperament—an explanation of the alleged insobriety of a people who, it is certain, do really consume so little intoxicating drink.[1]

[1] Good-fellowship is an enemy to sobriety—not for the vulgar reason that it provokes to the passing of the bottle, but because it makes what is drunk have a greater apparent effect. It is familiar to the knowing ones, that if a

This influence of temperament, in connection with that of climate, has probably something to do also with the great evils which are said to arise from the use of ardent spirits among the European races settled in North America. These, as is well known, have of late years given rise to much discussion—to strenuous efforts, on the part of the benevolent, to check the consumption of fermented liquors—and to the passing of what is called the Maine Law, for the purpose of effectually repressing it.

4°. Influence of Ardent Spirits.—In the ardour of this crusade against fermented liquors, statements have been hastily made by over-zealous champions of total abstinence, which are not quite borne out by chemical and physiological researches.

Ardent spirits of every variety are little else than alcohol diluted with a large proportion of water, and flavoured with a minute admixture of volatile oil, the precise action of which upon the system is not known. They contain none, therefore, of the common forms of nutritive matter which exist in our usual varieties of animal and vegetable food. It does not follow from this, however, as some have too broadly alleged, that they are incapable of serving any useful purpose in the animal economy. On the contrary, it is ascertained of ardent spirits—

First, That they are in a measure burnt in the body, and, by the changes they undergo in the blood, supply a portion of that heat and energy which are a necessity of life. They so far, therefore, supply the place of food—of the fat and starch, for example—which we usually eat. Hence a schnapps, in Germany, with a slice of lean dried meat, makes a mixture like that of the starch and gluten in our bread, which is capable of feeding the body. So we either add sugar to milk, or take spirits along with it (old man's milk), for the purpose of adjusting the proportions of the ingredients more suitably to the constitution, or to the circumstances in which it is to be consumed.

Secondly, That they diminish the absolute amount of carbonic acid, urea, and earthy phosphates usually given off by

man wishes to drink, he had better let his companions *do all the talking*. "Gin ye're gaun to drink, sir, dinna ye talk muckle." Here the temperament of the mercurial and excitable tells at once.

the lungs and the kidneys. They thus lessen, as tea and coffee do (p. 173), the natural waste of the fat and tissues, and they necessarily diminish, in an equal degree, the quantity of ordinary food which is requisite to keep up the weight of the body. In other words, they have the property of making a given weight of food go further in sustaining the strength and bulk of the body. This is a very different thing from the preventing of the digestion and assimilation of food which their excessive use occasions. And in addition to the saving of material thus effected, they ease and lighten the labour of the digestive organs, which, when the stomach is weak, is often a most valuable result. "Persons accustomed to the use of wine," says Liebig, "when they take cod-liver oil, soon lose their taste for wine. Since the establishment of temperance societies it was thought fair, in many English families, to compensate in money those servants who took the pledge, and no longer drank beer, for the former daily allowance of beer; but it was soon found that the monthly consumption of bread increased in a striking degree, so that the beer was twice paid for: once in money, and a second time in its equivalent in bread."

In comparing the physiological effects of fermented liquors with those of distilled spirits, we must not forget the marked diuretic action of the latter. An illustration is afforded by the case of a number of men employed on the Thames. Of these men, half drank porter, half spirits. Dr Garrod tells us that several of the porter-drinkers were attacked with gout, while all the spirit-drinkers escaped; the uric acid in the blood of the latter being more freely removed.

Hence fermented liquors, if otherwise suitable to the constitution, exercise a beneficial influence upon old people, and other weakly persons whose fat and tissues have begun to waste—in whom the process of digestion, that is, does not replace the tissues as fast as they naturally waste. This lessening in weight or substance is one of the most usual consequences of the approach of old age. It is a common symptom of the decline of life. The stomach either does not receive or does not digest food enough to replace that which is daily removed from the substance of the body. Weak alcoholic drinks arrest or retard, and thus diminish the daily amount of this loss of substance. They gently stimulate the

digestive organs also, and help them to do their work more fully and faithfully; and thus the body is sustained to a later period in life. Hence poets have called wine "the milk of the old," and scientific philosophy owns the propriety of the term. If it does not nourish the old so directly as milk nourishes the young, yet it certainly does aid in supporting and filling up their failing frames. And it is one of the happy consequences of a temperate youth and manhood, that this spirituous milk does not fail in its good effects when the weight of years begins to press upon us. But the water, the organic and inorganic salts, the odorous ethers, the bitter and other extractives, as well as the sugar in the various kinds of fermented liquor, must all be taken into account if we are to understand the physiological effects of these drinks. To a moist and cold climate and dull skies must be attributed some of the intemperance of northern regions. Continuous brightness of weather and light dry air favour sobriety.

All this, of course, in no way justifies the indulgence in fermented liquors of any kind to excess, or palliates the moral evils to which this excess invariably gives rise. The good results I have spoken of follow only from a moderate use of them. But the peculiar danger attendant upon the consumption of intoxicating drinks arises from their extreme seductiveness, and from the all but unconquerable strength of the drinking habit when once formed. Their peculiar malignity appears—where they have once obtained a mastery—in their becoming the parent and nurse of every kind of suffering, immorality, and crime. How difficult is it to forge a chain sufficiently strong to restrain men from alcoholic drink! In an early number of the 'Band of Hope Review' it was stated that, of 500,000 persons who had taken the pledge in the United States, 350,000 had broken it! Have the same proportion broken other solemn vows?

"Who hath woe?" says Solomon; "who hath sorrow? who hath contentions? who hath babbling? who hath wounds without cause? who hath redness of eyes? They that tarry long at the wine; they that go to seek mixed wine. Look not thou upon the wine when it is red, when it giveth his colour in the cup, when it moveth itself aright. At the last it biteth like a serpent, and stingeth like an adder."

5°. Adulteration of Fermented Liquors.—The real

strength of pure fermented liquors depends, as we have seen, on the proportion of alcohol they contain. But in various countries adulterating substances are added to them, often of a narcotic kind, for the purpose of imparting flavour, or a fictitious or apparent strength.

Thus, to malt-beer, in England, quassia-chips and chiretta-roots give extra bitterness; the *Ledum palustre* and *Ledum latifolium* have been used in North Germany; the *Achillea Millefolium*, or yarrow, in Dalecarlia; and the seeds of *Datura Stramonium*, or thorn-apple, in Russia, in India, and formerly in China. In Java, *ragi* cakes made of onions, black pepper, and capsicums, are fermented with boiled rice, to give a similar strength to rice-beer.

To grape-wine poppy-heads are now added in Persia. In ancient Palestine frankincense was added, especially to the wine given to criminals, for the purpose of stupefying them before the execution began; and in ancient Greece, sea-water in the proportion of 1 of water to 50 of wine, with the view of aiding digestion, and preventing its affecting the head.

Mastic is the name given to a kind of liqueur in use throughout the Levant and in the Grecian Isles. The best comes from Chios. It is a strong spirit, in which an aromatic resin or balsam has been dissolved, and is drunk with water. Some Greek wines at Constantinople are rendered bitter by an infusion of fir-cones. Chartreuse contains pine, anise, and angelica oils.

To ardent spirits, seeds of thorn-apple are added in India; and in England, Malagueta pepper with capsicum, calamus, and juniper-berries, to give a hot strong flavour to London gin.

These substances are all foreign to the true nature and composition of the liquors we ferment. They add nothing to the amount of alcohol contained in these liquors. They affect their quality generally by introducing narcotic or stimulating ingredients. The chemical properties of most of these narcotic ingredients, and their action upon the system, will be treated of in the immediately succeeding chapters upon the "Narcotics we Indulge in." But we cannot refrain from referring here to a substitute for alcohol which is actually now used in some parts of Ireland. It is a liquid derived from alcohol, being the oxide instead of the hydrate of ethyl.

Its employment for producing a rapid, and, happily, transitory state of intoxication, appears to date from about 1846-47, after the crusades of Father Mathew. When he expelled alcohol at the front door ether came in at the back. Dr B. W. Richardson has lately[1] described a visit he paid to Draper's Town from Ballymena. In the lower and business part of the town the smell of ether was distinctly perceptible. The dose taken is from a quarter to half an ounce, but now and then two or three ounces are tossed off at once. It is sold to the local dealers at 1s. 3d. the pint, and is made from methylated spirit. There are three stages in ethereal intoxication, the first indicated by hysterical laughter and loquacity; the second often accompanied by violent or riotous conduct; in the third the subject becomes dead drunk. In half an hour recovery is tolerably complete.

[1] Gentleman's Magazine, Oct. 1878.

CHAPTER XV.

THE NARCOTICS WE INDULGE IN.

TOBACCO.

Man's wants progressive; how he ministers to them.—Narcotics now in use in different parts of the world; map of their distribution.—Tobacco brought to Europe from America.—Its rapid spread over the globe.—Its extended use.—Opposition encourages it.—Is it indigenous in China as well as in America?—Present consumption in the United Kingdom.—It is rapidly increasing.—Circumstances which affect the quality of tobacco.—Where the best qualities grow.—Forms in which tobacco is used.—Manufacture of snuff.—Effects produced by tobacco.—It soothes and excites.—Influence of climate, constitution, and temperament in modifying its effects.—Interesting physiological facts.—Does it necessarily provoke to dissipation?—What is the tobacco reverie?—Chemical ingredients of the tobacco: the volatile oil; the volatile alkali; the alkalies produced during smoking; the empyreumatic oil.—Proportion of these poisonous substances is variable.—Chemical differences between smoking, chewing, and snuffing.—Cause of diversities in the quality of tobacco.—Adulterations of tobacco.—The ash of the tobacco-leaf.—The growing of tobacco an exhausting culture.

Akin to the intoxicating liquors we consume are the narcotic substances we indulge in; and if the history of the former, in their relations to the social state, be full of a melancholy interest, that of the latter is still more striking and extraordinary. I may say, indeed, that to the economical statist, not less than to the physiologist and psychologist, the connection of man with the narcotics in common use, in different countries, forms one of the most wonderful chapters in his entire history.

In ministering fully to his natural wants and cravings, man passes through three successive stages.

First, the necessities of his material nature are provided for. Beef and bread represent the means by which, in every country, this end is attained. And among the numerous forms of animal and vegetable food which different nations make use of in the place of these two staples of English life, a considerable amount of similarity in chemical composition prevails. Exactly the same gluten and starch and fat are supplied to the body in every country; while under very varied conditions of climate and of natural vegetation, the experience of man has led him everywhere to adjust in a measure the chemical constitution of the staple forms of his diet to the chemical wants of his living body.[1]

Next, he seeks to assuage the cares of his mind and to banish uneasy reflections. Fermented liquors are the agents by which this is effected. And here also it is interesting to remark, not only that this lightening of care is widely and extensively attained, but that the chemical substance, by the use of which it is brought about, is everywhere one and the same. Savage and civilised tribes, near and remote—the houseless barbarian wanderer, the settled peasant, and the skilled citizen—all have found out, by some common and instinctive process, the art of preparing fermented drinks, and of procuring for themselves the enjoyments and miseries of intoxication. And thus, whatever material is employed for the purpose, whether the toddy of the palm-tree, the sap of the aloe, the juice of the sugar-cane, the syrup of honey, the must of the grape, the expressed liquor of the apple and pear, the wort of malted grain, or the milk of the Tartar mare—in every instance the substance called alcohol is produced by the fermentation, and forms the intoxicating ingredient of the liquor.

And lastly, he desires to multiply his enjoyments, intellectual and animal, and for the time to exalt them. This he attains by the aid of narcotics. And of these narcotics, again, it is remarkable that almost every country or tribe has its own, either aboriginal or imported; so that the universal instinct of the race has led, somehow or other, to the universal supply of this want or craving also.

[1] See "The Bread we Eat," and "The Beef we Cook."

The aborigines of Central America rolled up the tobacco-leaf, and dreamed away their lives in smoky reveries, ages before Columbus was born, or the colonists of Sir Walter Raleigh brought it within the precincts of the Elizabethan court. The coca-leaf, now the comfort and strength of the Peruvian muletero, was chewed as *he* chews it, in far-remote times, and among the same mountains, by the Indian natives whose blood he inherits. The use of opium, of hemp, and of the betel-nut among Eastern Asiatics, mounts up to the times of most fabulous antiquity. The same probably is true of the pepper-plants among the South Sea Islands and the Indian Archipelago, and of the thorn-apples used among the natives of the Andes, and on the slopes of the Himalayas; while in northern Europe the ledum and the hop, and in Siberia the narcotic fungus, have been in use from time immemorial.—(*See* Map, p. 265.)

As from different plants, in different parts of the world, the favourite intoxicating liquor was obtained, so from different plants the favourite narcotic was extracted by different races of men. But this important difference prevails between the two classes of indulgences, that while in all the fermented liquors, as I have said, the same alcohol or intoxicating spirit exists, each narcotic in use contains its own peculiar principle. From whatever source obtained, the fermented liquor produces nearly the same effect upon the human system. But each narcotic indulgence produces its own peculiar and special effect. Tobacco, and opium, and hemp, and coca, and the hop, and the toad-stool, while they all exercise a narcotic influence upon the human frame, do so in a form and with modifications which in each case are peculiar, in many respects full of interest, and always worthy of deep study and consideration. These narcotic substances, therefore, occupy an important place in the chemistry and chemico-physiology of common life.

I. Tobacco.—Of all the narcotics I have mentioned, tobacco (fig. 47) is in use over the largest area, and among the greatest number of people. Opium is probably next to it in these respects, and the hemp plant occupies the third place. This is exhibited to the eye in the map which I have attached to the present chapter. A glance at this map shows the original

home of each of the most important narcotics, as well as the parts of the earth in which each is known to be at present cultivated.

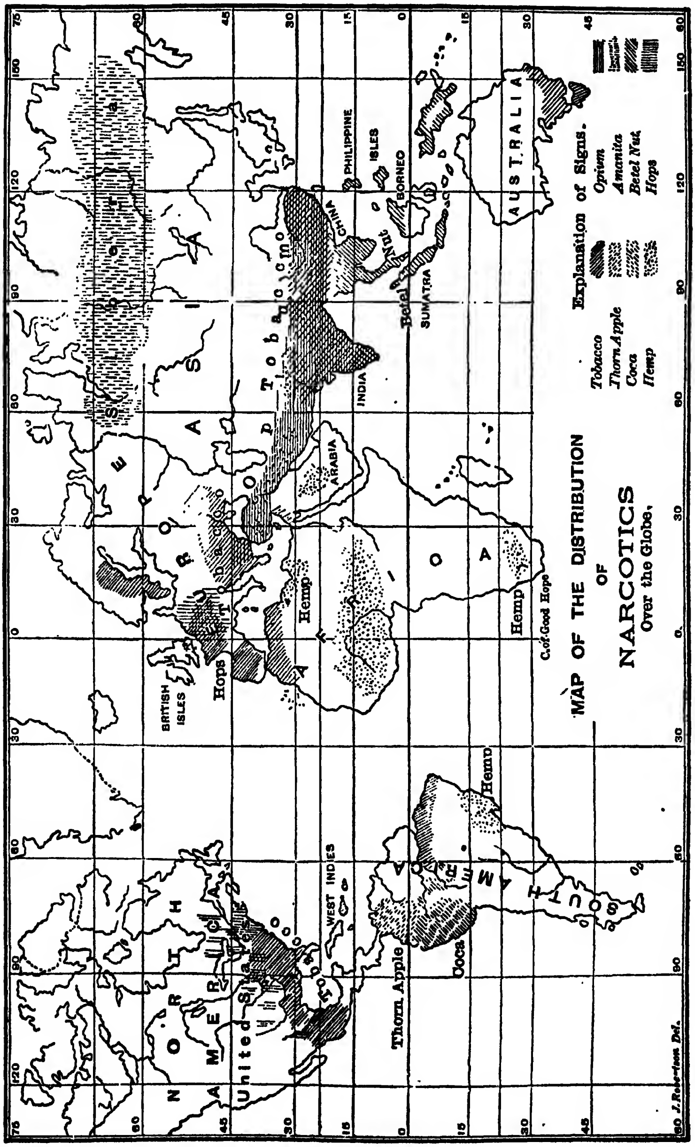
Tobacco is believed to be a native of tropical America; at all events, it was cultivated and used by the native inhabitants of various parts of that continent long before its discovery by Europeans.[1] In 1492, Columbus found the chiefs of Cuba smoking cigars, and Cortes met with it afterwards, when he penetrated to Mexico. From America it was introduced into Spain by the Spaniards, it is not certain in what year. In 1560 it was brought to France by Nicot, and in 1586 to England by Sir Francis Drake, and the colonists of Sir Walter Raleigh. Into Turkey and Arabia, according to Mr Lane, it was introduced about the beginning of the seventeenth century, and in 1601 it is known to have been carried to Java. Since that time both the cultivation and the use of the plant have spread over a large portion of the habitable globe.

Fig. 47.

Nicotiana tabacum—
The Virginian Tobacco.
Scale, 1 inch to a foot and a half.

Thus the different parts of America in which it is now grown include Canada, New Brunswick, the United States, Mexico, the western coast as far as 40° south latitude, Brazil, Cuba, Trinidad, Jamaica, and the other West India Islands. In Africa it is cultivated on the Red Sea and the Mediterranean, in Egypt, Algeria, the Canaries, along the western coast, at the Cape of Good

[1] The history of tobacco and its uses has been elaborately compiled by Tiedmann, 'Geschichte des Tabaks und ähnlicher Genussmittel,' 1854—an abstract of which is given by Von Bibra, 'Die Narkotischen Genussmittel und der Mensch,' 1855.


MAP OF THE DISTRIBUTION
OF
NARCOTICS
Over the Globe.
Explanation of Signs.
Tobacco
Thorn Apple
Coca
Hemp
Opium
Amanita
Betel Nut
Hops
BRITISH ISLES
Hops
Hemp
ARABIA
INDIA
CHINA
SUMATRA
BORNEO
PHILIPPINE ISLES
Betel Nut
AUSTRALIA
C. of Good Hope
WEST INDIES
United States
Thorn Apple
Coca
J. Robertson Del.

Hope, and at numerous places in the interior of the continent. In Europe, it has been raised with success in almost every country,[1] and it forms at present an important agricultural product in Hungary, Germany, Flanders, and France. In Asia, it has spread over Turkey, Persia, India, Thibet, China, Japan, the Bahamas, the Philippine Islands, Java, Ceylon, and to Australia and New Zealand. Among narcotic plants, indeed, it occupies a similar place to that of the potato among food-plants. It is the most extensively cultivated, the most hardy, and the most tolerant of changes in temperature, altitude, and general climate. From the equator to the fiftieth degree of latitude it may be raised without difficulty, though it grows best within thirty-five degrees of latitude on either side of the equator. The finest qualities are raised between the fifteenth degree of north latitude, that of the Philippines, and the thirty-fifth degree, that of Lattakia in Syria.—(*See* Map.)

1°. Extensive use of Tobacco.—And the use of the plant has become not less universal than its cultivation. Next to salt, it is supposed by some to be the article most extensively consumed by man. Tea alone can compete with it; for although it may not be in use over so large an area, tea is probably consumed by as great a number of the human race.[2] In America, tobacco is met with everywhere, and the consumption is enormous. To its use in some parts of the United States, at the present moment, King James's description, in the opinion of many, applies more justly than to the practice in any other part of the world: "A custom loathsome to the eye, hateful to the nose, harmfull to the brain, dangerous to the lungs, and in the black stinking fume thereof neerest resembling the horrible Stygian smoake of the pit that is bottomless." In Paraguay, some fourteen or fifteen varieties of tobacco, each having its advocates, are grown.

In Europe, from the plains of sunny Castile to the frozen Archangel, and from the Ural to Iceland, the pipe, the cigar, and the snuff-box, are a common solace, among all ranks and conditions of man. In vain, when it first came among us, King James opposed it by his 'Counterblaste to Tobacco;' in

[1] In the canton Vaud in Switzerland tobacco worth £32,000 is annually raised.

[2] See what is said in the succeeding chapter as to the consumption of the hop in England.

vain Pope Urban the Eighth thundered out his bull against it; in vain was the use of it prohibited in Russia, and the knout threatened for the first offence, and death for the second. Opposition and persecution only excited more general attention to the plant, awakened curiosity regarding it, and tempted people to try its effects.

So, in the East, the priests and sultans of Turkey and Persia declared smoking a sin against their holy religion; yet the Turks and Persians have become the greatest smokers in the world. In Turkey, the pipe is perpetually in the mouth. In India, all classes and both sexes smoke. The Siamese chew moderately, but smoke perpetually. The Burmese of all ranks, of both sexes and of all ages, down even to infants of three years old, smoke cigars—(CRAWFORD). In China, where tobacco was not introduced until the close of the sixteenth century, the Emperor Tsung Ching issued a prohibitory edict in 1641 with about the same effect as King James's 'Counterblaste.' For in that empire the practice is so universal that every female, from the age of eight or nine, wears, as an appendage to her dress, a small silken pocket to hold tobacco and a pipe.

Indeed, from the extensive prevalence of the practice in Asia, and especially in China, Pallas argued long ago that the use of tobacco for smoking in those countries must be more ancient than the discovery of America. "Amongst the Chinese," he says, "and amongst the Mongol tribes, who had the most intercourse with them, the custom of smoking is so general, so frequent, and has become so indispensable a luxury; the tobacco-purse affixed to their belt so necessary an article of dress; the form of the pipes, from which the Dutch seem to have taken the model of theirs, so original; and, lastly, the preparation of the yellow leaves, which are merely rubbed to pieces, and then put into the pipe, so peculiar,—that they could not possibly derive all this from America by way of Europe, especially as India, where the practice of smoking is not so general, intervenes between Persia and China."

This opinion of Pallas, though probably untenable, has since been supported by high botanical authorities. Thus Meyen says: "It has long been the opinion that the use of tobacco, as well as its culture, was peculiar to the people of America; but this is now proved to be incorrect, by our present more exact acquaintance with China and India. The

consumption of tobacco in the Chinese empire is of immense extent, and the practice seems to be of great antiquity, for on very old sculptures I have observed the very same tobacco-pipes which are still used. Besides, we now know the plant which furnishes the Chinese tobacco; it is even said to grow wild in the East Indies."

According to MM. Huc and Gabet, the yellow tobacco of eastern Thibet and western China is the leaf of the *Nicotiana rustica.* In flavour it resembles the finest Syrian tobacco, which is the produce of a variety of *N. Tabacum,* and owes its peculiar properties to the mode of curing the leaf. The tobacco of central and southern India is the *Nicotiana Tabacum,* or Virginian tobacco—(HOOKER).

The common green tobacco (fig. 48) is a smaller plant than the Virginian, being only 3 to 5 feet in height, and has shorter and broader leaves and smaller flowers, with rounded instead of pointed segments. It is the species generally cultivated in Russia, Sweden, and North Germany, and two varieties of it are grown in some parts of Ireland, under the names of Oronooko and Negro-head. It is said, I do not know upon what authority, to have been imported to Britain from America in 1570. The variety cultivated in China is still smaller than the one represented in fig. 48.

Fig. 48.

Nicotiana rustica—
Common green Tobacco.
Scale, 1 inch to the foot.

If this be really the species cultivated in western China, the argument of Meyen loses much of its weight, and the opinion that eastern Asia did not derive the use of tobacco from America must rest chiefly on the general prevalence and antiquity of the custom in China. Other late writers, indeed, dissent from this opinion, and consider that there can hardly be a doubt but that tobacco was introduced into the different countries of the East from Europe, and by Europeans—(CRAWFORD). Other considerations, however, which it would be out of place here to discuss, incline me to

regard its introduction in this way as less certain than it appears to Mr Crawford. The truth may possibly be (though the whole botany of tobacco is still obscure), that species of the tobacco plant are native to Europe and Asia as well as to America, and that only the *custom* of using them as narcotics was introduced into western Europe from the New World.

But whichever of these opinions we adopt in regard to the East, still, one of the most remarkable circumstances connected with the history of tobacco is the rapidity with which its growth has spread, and its consumption increased, in those countries to which we are certain that the use of it came from America. In 1662, the quantity raised in Virginia, then the chief producer of tobacco on the American shores of the Atlantic, was only 60,000 lb., and the quantity exported from that colony in 1689 only 120,000 lb. During the 190 years which have since elapsed, the produce of this coast has risen to twice as many millions of pounds!

The enormous extent to which its use has increased in our own country, may be judged of from the fact, that while in the above-mentioned year (1689) the total importation was only 120,000 lb. of Virginian tobacco, part of which was re-exported, the consumption in the United Kingdom is at present above 50,000,000 lb.! Thus the quantity entered for home consumption in—

1857 was	32,856,913 lb.
1867 ,, ...	40,720,767 ,,
1875 ,, ...	49,051,830 ,,

And to this must be added the contraband tobacco, which the heavy duty of 3s. 6d. a lb. tempts the smuggler to introduce.

That the consumption among us is still rapidly on the increase, appears from the above numbers; but it is more clearly shown by the following table, which exhibits the quantities consumed at each of the last six decennial periods:—

Years.	Total Consumption.	Population.	Consumption per head.
1821	15,598,152 lb.	21,282,960	0 lb. $11\frac{3}{4}$ oz.
1831	19,533,841 ,,	24,410,439	0 ,, $12\frac{3}{4}$,,
1841	22,309,360 ,,	27,019,672	0 ,, $13\frac{1}{4}$,,
1851	28,062,841 ,,	27,452,692	1 ,, $0\frac{3}{4}$,,
1861	35,413,846 ,,	28,974,362	1 ,, $3\frac{1}{2}$,,
1871	42,656,658 ,,	31,513,442	1 ,, $5\frac{1}{2}$,,

These numbers show that, during the last fifty years, the consumption of the United Kingdom has nearly doubled. The number of retail dealers in tobacco was 83,493 in 1801; it is now about 250,000.

The duty on unmanufactured tobacco was 3s. a lb., and 5 per cent, from the year 1842 till 1858; 3s. 2d. a lb. from 1859 till the spring of 1878, when it was raised to 3s. 6d. The gross produce of the duty on the raw tobacco retained for home consumption in 1876 was £7,407,794. To this must be added the proceeds of the duty on the cigars, snuff, cavendish, and other manufactured tobaccos consumed in the country—say, £500,000.

In Europe generally, the consumption is restricted by the heavy duties imposed upon it; yet the consumption of the United Kingdom is said to be less than that of most of the other European nations. But in some of the States of North America the proportion greatly exceeds the European allowance of 1 to 5 lb. per head; while among Eastern nations, where no duty is imposed upon tobacco, it is believed to be greater still. Some twenty years ago Mr Crawford estimated the average consumption of tobacco by the whole human race of 1,000,000,000 at 70 ounces a-head, and the total produce and consumption of this favourite narcotic at 2,000,000 tons, or 4,480,000,000 lb! At 800 lb. an acre, this would require upwards of 5,500,000 acres of rich land to be kept constantly under tobacco cultivation. And since this calculation was made, not only has the estimated population of the world increased to 1,439,000,000, but the use of tobacco has extended, and its consumption per head notably increased. It is doubtful, however, if as large sums are now anywhere spent upon this indulgence as there were in England in the time of King James I., who speaks of "some of the gentry bestowing three and some four hundred pounds a yeere upon this precious stink."

2°. Varieties of Tobacco.—Many species of the tobacco plant have been enumerated: but most of these are now, however, regarded as varieties, though a few distinct species are still retained, of which different varieties are grown in different countries.

These facts possess an economical and chemical, as well as a botanical interest: for, on the one hand, the quality of the

tobacco grown in the same locality, and under the same circumstances, differs with the variety of plant cultivated; and, on the other, the proportions of the chemical ingredients for which tobacco is distinguished likewise differ with the species or the variety. Exactly the same facts are observed with the cinchona plant—that precious medicine.

Other circumstances also affect those sensible properties for which tobacco is prized. The climate, the soil, the mode of culture, the kind of manure applied, the period at which the leaves are gathered, the way in which they are dried and cured, the time they are kept in store, the distance to which they are carried to market, and the process by which they are prepared for use—all these circumstances exercise a well-known influence upon the quality of the leaf. Well-packed tobacco, like some wines, improves by a sea voyage. It undergoes by the way a species of fermentation, by which its flavour is mellowed. European tobacco is said to be much better when smoked in America than in its native Europe. The conditions for the most favourable development of the qualities of the leaf being so varied, there can be only few places in which they all conspire to the production of the most valuable crop. Hence, as is the case with the vine, and with the tea and coffee plants, the localities which yield tobacco in the greatest perfection are not only few in number, but generally very limited in extent.

The finest tobacco of America is produced in the island of Cuba, where, according to Heller, it is grown only in new sandy but fertile soils. That of the island of Luzon in the Philippines, from which the celebrated Manila cigars are made, is nearly equal to that of Cuba. A fine but strong tobacco is produced in the province of Cadoe in Java, where it is grown in a naturally rich soil alternately with rice, and without manure. Excellent tobacco is now grown in Jamaica and Fiji, while the cultivation has begun in the Bahamas. In Hindostan, a fine tobacco, known by the name of Bilsah, is grown in the province of Malwa, and in the province of Guzerat another fine variety called Kaira. All these are the produce of the *Nicotiana Tabacum*. In central Asia, the yellow tobacco of China and Thibet is peculiarly mild and agreeable, though, probably from its rarity, the inferior tobacco of India, when carried to Lhassa, sells as high as 30s. a lb.—

(HOOKER). In western Asia the most prized tobaccos are those of Lattakia (the ancient Laodicea) in Syria, and of Shiraz in Persia. Both of these, like the Chinese tobacco, are the leaf of varieties of the *N. Tabacum*, and not, as has been long supposed, of other and distinct species of *Nicotiana*, such as *N. rustica*, *N. persica*, and *N. repanda*. Thus the finest tobacco has a wide range of latitude, though the districts in which it is anywhere produced are, as I have said, very limited in extent. A warm summer appears to be necessary to the production of a delicately-flavoured leaf. That of temperate and cold regions is generally harsh and strong, as if it abounded more in the narcotic ingredients upon which the activity of tobacco principally depends. The mercantile values of the tobacco of different countries greatly differ from each other; and also, it will be found, that from the same country a tobacco worth 2d. per lb., and another worth 1s. or more, may come. The amount of manufactured tobacco imported into Great Britain in 1876 was 3,818,682 lb.; of unmanufactured, 76,814,974 lb. The imports of the latter were from the following countries:—

United States, .	61,644,985 lb.	Germany, .	655,312 lb.
Holland, . .	7,150,504 ,,	Philippines, .	217,210 ,,
Japan, . .	785,438 ,,	France, . .	1,475,854 ,,
Turkey, . .	724,669 ,,		

The commercial history of Dutch-grown tobacco is somewhat curious. In the valley of Guelderland—the Veluwe, as it is called—about 2,000,000 lb. of tobacco are raised. Of this nearly one-half is bought by the French Government for the supply of France. In that country it is used partly for cigars, and partly for making snuff. The rest of the Guelderland tobacco is shipped to North America, and even to Cuba, The fineness of the leaf, and its freedom from thick fibres. make it in request for the outer covering of cigars. In this case the market value of the tobacco is independent of its general quality or its chemical composition. Chinese tobacco is equally employed for covering cigars.

"The *tombeki*, a tobacco destined exclusively for the narghilé, comes from Persia. It is not cut like the other, but pressed, and broken in small morsels. It is of a darker colour than the other kinds, and so strong that it cannot be smoked until after two or three washings; and as it is liable to scatter, it is kept in glass jars, like a drug. Without tombeki, the

narghilé cannot be smoked; and it is vexatious that this tobacco is very difficult to procure in Europe; because nothing is more delicious, or more favourable to poetic reverie, than to inhale, in gentle puffs, while seated upon the cushions of a divan, this perfumed smoke, freshened by the water through which it passes, and which reaches you, after traversing a large circle of tubing, in which you entwine your arm, like an Arab snake-charmer playing with his serpents. It is the sybaritism of smoking carried to the highest degree of perfection."[1]

3°. Forms in which Tobacco is used.—Tobacco is used in nearly all countries for each of the three purposes of chewing, smoking, and snuffing. The first of these practices is in many respects the most disgusting, and is now rarely seen in this country except among seafaring men. On shipboard smoking is always dangerous, and often forbidden, while snuffing is expensive and inconvenient, and less perfectly satisfies the narcotic appetite. If the weed must be used, therefore, the form of chewing is more excusable in the sailor.

In some of the southern and western States of North America, chewing to an offensive extent prevails; and in Iceland, according to Madame Pfeiffer, tobacco is chewed and snuffed "with the same infatuation as it is smoked in other countries." The traveller in northern Sweden may have observed the *bunde* who accompanies or drives his post-horses, putting a large pinch of snuff from time to time into his mouth, thus applying to the wrong organ, as he conceives, the finely-powdered leaf. An Icelander applies the snuff to his nose, but in a peculiar manner. "Most of the peasants," says Madame Pfeiffer, "and even many of the priests, have no proper snuff-box, but only a box made of bone, and shaped like a powder-flask. When they take snuff they throw back the head, insert the point of the flask in the nose, and shake a dose of snuff into it. They then, with the greatest amiability, offer it to their neighbour—he to his; and so it goes round till it reaches the owner again."[2]

The box described in this passage is only a Highland horn *mull*, a little different in shape from those of modern fashion.

[1] Constantinople of To-day, by Théophile Gautier, p. 114.
[2] Madame Pfeiffer's Visit to Iceland, London edition, p. 179.

The Highlander lifts the powder to his nose with a little shovel; the Icelander, using the small end of the horn, at once pours it in. But among the Celto-Scandinavians of Northern Britain there is the same love of the powdered tobacco as in Iceland and northern Scandinavia, and the same amiability in handing round the box as is seen in primitive Iceland. Are these not lingering relics of similar social customs, which still point to the ancient unity and common origin of the three now disconnected peoples?

The Brazilians are great snuff-takers, and always offer the box to a welcome visitor. The etiquette is to take the offered pinch with the left hand. They do not smoke much.

"Smoking is a necessity of existence to the Turks; one could almost fancy it a part of his religion. The tobacco, cut very fine, and disposed in long, silky tufts, of a pale tint, is laid in masses upon shelves, and arranged with reference to its price and quality. The principal qualities are four in number—namely, *iavach* (sweet), *orta* (medium), *dokan-aklen* (piquant), and *sert* (strong); and are sold at from eighteen to twenty piastres (from 3s. 6d. to 4s. English) for an *ocque*—a quantity equivalent to about 2½ lb. These tobaccos, of graduated strength, are smoked in chibouques, or rolled into cigarettes; the use of which last is beginning to be very general in Turkey.'[1]

"In general, the Turks and Arabs of Egypt are great smokers, but not those of the other tribes. Before the Turkish invasion, tobacco-smoking (*dogahn*, smoke) was unknown to the Schaigies, and even yet it is not practised by anything like a fourth part of these natives. Among the Mograbins it is hardly known at all; but chewing, each portion of tobacco being accompanied by a piece of natron, is the order of the day. Master and servant, rich or poor, all carry about with them a bag with tobacco and pieces of natron in it; and they do not carry their quid as Europeans who indulge in this bad habit do, in their cheek, but in front, between the teeth and upper lip. The blacks of Gesira have another method of enjoying this plant. They make a cold infusion of tobacco, and dissolve the natron in it. Of this precious mixture, called *bucca*, they take a mouthful, which they keep rinsing about in their mouths for some quarter of

[1] Constantinople of To-day, by Théophile Gautier, p. 114

an hour ere they eject it. So much do they delight in this bucca, that it is the highest treat they can offer to their dearest friends. The whole party sit in solemn silence, the bucca-cup makes its round, each takes his mouthful, and nothing is heard save the gurgling and working inside the closed mouths: at such a moment these blacks will give no reply to the most important questions, as to open the mouth would be to lose the cherished bucca, so signs are only used. All these races, however, blacks and all, are much addicted to snuff-taking (*nuschuk*). The snuff they usually carry in small oval-shaped cases, made out of the fruit of the Doum-palm; these have a very small opening at one end, stopped up by a wooden peg, and the snuff is not taken in pinches, but shaken out on the back of the hand."[1]

The practice of using snuff is said to have come into England after the Restoration, and to have been brought from France. The name of rappees (*rapés*), which we give to our moist snuffs, is certainly of French extraction, and a large proportion of the tobacco now used in France is in the form of snuff.

For the smoker and chewer, tobacco is prepared in various forms, and sold under many names. The dried leaves, coarsely broken, are sold as canister or knaster. When moistened, compressed, and cut into fine threads, they form cut or shag tobacco. Softened with molasses, or with syrup, and pressed into cakes, they are called Cavendish or Negrohead, and are used indifferently either for chewing or smoking. Moistened in the same way, and beaten until they are soft, and then twisted into a thick string, they form the pigtail or twist of the chewer. Cigars are made of the dried leaves deprived of their midribs, sprinkled sometimes with a solution of saltpetre to make them burn better, and rolled up into a short spindle. When cut straight across or truncated at each end, as is frequently the custom at Manila, they are distinguished as cheroots. In Mexico, and indeed in some other countries as well, tobacco is used only in cigars.

In preparing them for the snuff-taker, the dried leaves are sprinkled with water, laid in heaps, and allowed to heat and ferment from one to six months. During this fermentation a chemical decomposition takes place in the leaves, and they

[1] Werne's African Wanderings, p. 127.

give off at first nicotine and ammonia,[1] and afterwards water and acetic acid. They are then reduced to powder, moistened with salt and water, and put into close boxes. Here they again heat and ferment. This gives them an agreeable ethereal odour and the well-known pungency of snuff. Rappees, or moist snuffs, are usually prepared from the soft part of the leaves. Dried snuffs, like the Scotch and Welsh, are made from the fibres or midribs. The former are variously scented to suit the taste of the customer. In some countries snuff is mixed with wood-ashes or lime, and is even made more pungent still by adding ground cayenne pepper. On the west coast of Africa the Mushicongos and the natives of the Lombo country use snuff so prepared, not taking a mere pinch as we do, but drawing it up from the palm of the hand through their capacious nostrils. If their hands are occupied, a stubbly moustache, grown for the purpose, serves as a means of carrying and conveying the powder to their nostrils.

The quality and flavour of the snuff are materially affected by the variety of tobacco used—by the part of the leaf from which the snuff is formed—by the extent to which the two fermentations are carried—by the degree of heat at which the leaves are dried or roasted for dry snuffs—and by the length of time during which they are exposed to this heat. The kind of influence exercised by the fermentation and the roasting will appear, when I shall have described the properties of the ingredients on which the activity of tobacco upon the human system depends. And it must not be forgotten that a great variety of "liquors," "pickles," or "spices," are in use to add or develop special flavours in tobacco.

As to a fourth, and, we will hope, a rare employment of tobacco, it need only be said that it has been used to drug beer, and so to increase its stupefying property.

4°. Effects of Tobacco.—In whichever of the three ways it is used, the effects produced by tobacco appear to be much the same in kind; they differ chiefly in degree. But, extensively as it is consumed, it is remarkable how very few persons can state distinctly the effects which tobacco produces upon them—the kind of pleasure which the daily use of it

[1] Ammonia is an invisible kind of air or gas, which gives its smell to the hartshorn (liquid ammonia) and to the common smelling-salts (carbonate of ammonia) of the shops. It consists of the two gases, nitrogen and hydrogen.

gives them—why they began, and for what reason they continue, the indulgence. If the reader be a consumer of tobacco, let him ask himself these questions, and he will be surprised how little satisfactory the answers he receives will be. In truth, few have thought much on these points—have cared to analyse their sensations when under the narcotic influence of tobacco—or if they have analysed them, would care to tell truly what kind of relief it is which they seek in the use of it.

"In habitual smokers," says Dr Pereira, a high authority in such matters, "the practice, when moderately indulged, provokes thirst, increases the secretion of saliva, and produces that remarkably soothing and tranquillising effect on the mind, which has caused it to be so much admired and adopted by all classes of society, and by all nations, civilised and barbarous."[1] Smoked to excess, and especially by persons unaccustomed to its use, it produces nausea, vomiting, in some cases purging, universal trembling, staggering, convulsive movements, paralysis, torpor, and death. Cases are on record of persons killing themselves by smoking seventeen or eighteen pipes at a sitting. With some constitutions it never agrees; but both Dr Pereira, and Dr Christison in his 'Treatise on Poisons,' agree that "no well-ascertained ill effects have been shown to result from the habitual practice of smoking." Dr Prout, an excellent chemist, and a physician of extensive medical experience, whom all his scientific contemporaries held in much esteem, was of a different opinion. But even he expresses himself obscurely as to its being generally deleterious when moderately indulged in.[2]

[1] Materia Medica, 3d edition, p. 1431.

[2] I give Dr Prout's own words: "Tobacco disorders the assimilating functions in general, but particularly, as I believe, the assimilation of the saccharine principle. Some poisonous principle, probably of an acid nature, is generated in certain individuals by its abuse, as is evident from their cachectic looks, and from the dark and often greenish-yellow tint of the blood. The severe and peculiar dyspeptic symptoms sometimes produced by inveterate snuff-taking are well known; and I have more than once seen such cases terminate fatally with malignant disease of the stomach and liver. Great smokers, also, especially those who employ short pipes and cigars, are said to be liable to cancerous affections of the lips. But it happens with tobacco as with deleterious articles of diet, the strong and healthy suffer comparatively little, while the weak and predisposed to disease fall victims to its poisonous operation. Surely, if the dictates of reason were allowed to prevail, an article so injurious

The effects of chewing are of a similar kind; but the vapours which accompany the smoke of burning tobacco are more penetrating, and act more speedily than the juice which is squeezed from the leaf, as it is chewed, and occasionally turned over in the mouth. Those of snuffing, also, are only less in degree. The same influence of tobacco which, when the *quid* or the pipe is used, promotes the flow of saliva in the mouth, manifests itself when snuff is taken, in producing sneezing, and in increasing the discharge of mucus from the nose. The excessive use of snuff, however, blunts the sense of smell, alters the tone of voice, and occasionally produces dyspepsia and loss of appetite. In rarer cases it ultimately induces apoplexy and delirium.

The author of 'A Tour Round my Garden' says: "I must confess I smoke, my friend. I acquired the habit among fishermen and sailors, and I practised it for another reason. I formerly fell in with people who wearied and annoyed me. I was to be with them while they were talking, but I had a great objection to talking too; I had absolutely nothing to say to them. I found it polite and convenient to make them smoke and smoke myself; they spoke less, and I did not speak at all. Now, although I do smoke sometimes, I am likewise sometimes whole months without taking down my pipe. I never smoke in my garden; I am not willing to mingle the odour of tobacco with the perfume of my flowers. What charming travellers are all these flowers, assembled together from all parts of the world! Tobacco comes from America, the Queen Marguerite comes from China; the heliotrope from Peru; the day-lily from Portugal; the rose-laurel from Greece; the azaleas are originally from India; the tulip is from Asia. I could write a capital history of the voyages I have failed to make. I was very nearly going to Greece, to see the wild uncultivated rose-laurels blow, with their roots in the waters of the Eurotas. I learnt that quite as good were to be seen in the south of France, so I did not go. There are things which we do all at once, or else never do at

to the health, and so offensive in all its modes of enjoyment, would speedily be banished."

Yet reason is not so certainly on Dr Proût's side; for Locke says, "Bread or tobacco may be neglected, but reason at first recommends their trial, and custom makes them pleasant."

all. The excess of the thing gives you an excess of resolution; and in making the tour of the world, to have descended your own staircase is to have performed a quarter of the undertaking."

It is chiefly because of "the soothing and tranquillising effect it has on the mind," as it is expressed by Dr Pereira, that tobacco is indulged in. And were it possible, amid the teasing paltry cares, as well as the more poignant griefs of life, to find a mere material soother and tranquilliser, productive of no evil after-effects, and accessible alike to all—to the desolate and the outcast equally with him who is rich in a happy home and the felicity of sympathising friends—who so heartless as to wonder or regret that millions of the world-chafed should flee to it for solace! I confess, however, that in tobacco I have never found this soothing effect. This, no doubt, is constitutional; for I cannot presume to ignore the united testimony of the millions of mankind who assert, from their own experience, that it does produce such effects. Its influence, indeed, appears very much to depend upon the constitution and natural temperament of the consumer. Among Europeans this is manifested chiefly by the difference of its effects upon different individuals, causing some to reject and avoid it, while others constantly and eagerly indulge in it. But in other countries, as in North America, the effects it produces separate, physiologically, entire regions from each other. The States of intellectual New England and New York, for example, taken as a whole, appear to dislike the use of tobacco; at least there is a very large, thinking, and conscientious body of men in these States, who are exerting themselves to repress and suppress the use of the weed, and who even desire a legislative enactment to prevent it. The western and southern States, on the other hand, largely, and almost universally, indulge in tobacco; and one cannot travel from New York towards those States without coming in contact with the practices of smoking and chewing in their most offensive forms. In the one region the mass of thoughtful and religious men condemns the use of tobacco, chiefly, I believe, on moral grounds; in the other region, a vast majority of the thoughtful and religious, as well as almost universal practice, uphold and maintain it. The Wahabees in northern Africa smoke no tobacco: the Parsees of India abominate it.

In Russia, the *Starovierze*, or "Old Believers," a very moral sect of dissenters from the Greek Church, look with horror on the use of tobacco—(De Lagny).

These are very interesting physiological facts, well worthy of calm study on the part of those whose feelings will permit them to look at the matter coolly, and whose minds are capacious enough to take in and balance contradictory opinions and testimony. Climate gradually affects constitution and temperament. It has so affected, I believe, but in different ways, the two regions of North America to which I have referred. Upon constitutions and temperaments so diversely altered, the constituents of tobacco act differently, and thus the broadest assertions, both of the abusers and of the defenders of tobacco in the several regions, may be strictly true, though decidedly opposed to each other, and entirely contradictory. There is much wisdom in the Irish form of equivocal assent to a doubtful assertion: "True for *you*"—meaning, "with my knowledge you would think differently."

Again, in New England, it is alleged as a strong moral argument against the use of tobacco, that it provokes thirst and leads almost necessarily to excess in drinking, to frequent intoxication, and to all the evils which flow from it. This, which is sometimes alleged at home, and often with truth, is singularly at variance with its reputed effects among the Asiatic nations. Mr Lane, the translator of the 'Arabian Nights,' says, "that being in a slight degree exhilarating, and at the same time soothing and unattended by the injurious effects which proceed from wine, it is a sufficient luxury to many who without it would have recourse to intoxicating beverages, merely to pass away hours of idleness." Mr Layard, whose intercourse with Eastern nations has been most extensive, entertains the same opinion; while Mr Crawford, who has also seen much of Eastern life, "thinks it can hardly be doubted that tobacco must, to a certain extent, have contributed to the sobriety both of Asiatic and European nations." [1]

These opposite facts form another interesting physiological study. In North America the smoking of tobacco provokes to alcoholic dissipation; in Asia it restrains the use of intoxicating drinks, and takes their place. How complicated are the causes out of which these different effects spring! Cli-

[1] Journal of the Statistical Society, March 1853, p. 52.

mate, temperament, bodily constitution, habits, and institutions, act and react upon each other; and according to the peculiar result of all these actions in this or that country, the same narcotic substance produces upon the mass of the people a salutary, a harmless, or a baneful effect!

Generally, of the physiological action of tobacco upon the bulk of mankind, and apart from its moral influences, it may be received as characteristic of this substance among narcotics—

First, That its greater and first effect is to assuage and allay pain, and soothe the system in general.

Secondly, That its lesser and second, or after effect, is to excite and invigorate, and at the same time give steadiness and fixity to the powers of thought.

To what special action of its chemical constituents on the brain and nerves the soothing action and the pleasing reverie, so generally spoken of, are to be ascribed, we can only guess. According to Dr Madden, "the pleasure of the reverie consequent on the indulgence of the pipe, consists in a temporary annihilation of thought. People really cease to think when they have been long smoking. I have asked Turks repeatedly what they have been thinking of during their long smoking reveries, and they replied, 'Of nothing.' I could not remind them of a single idea having occupied their minds; and in the consideration of the Turkish character there is no more curious circumstance connected with their moral condition."[1]

Is it really a peculiarity of the Turkish or Moslem temperament, that tobacco soothes the mind to sleep while the body is alive and awake? That such is not its general action in Europe, the study of almost every German writer can testify. With the constant pipe diffusing its beloved aroma around him, the German philosopher works out the profoundest of his results of thought. He thinks and dreams, and dreams and thinks, alternately; but while his body is soothed and stilled, his mind is ever awake. From what I have heard such men say, I could almost fancy they had in this practice discovered a way of liberating the mind from the trammels of the body, and of thus giving it a freer range and more undisturbed liberty of action. I regret that I have never found it act so upon myself.

[1] Travels in Turkey, vol. i. p. 16.

Andersson, in his 'Travels to Lake Ngami,' thus describes the way in which the Damaras, a tribe of South-western Africans, smoke, and the effects of tobacco so consumed upon them: "A small quantity of water is put into a large horn three or four feet long. A short clay pipe, filled with either tobacco or hemp, is then introduced, and fixed vertically into the side near the extremity of the narrow end, communicating with the interior by means of a small aperture. This being done, the party present place themselves in a circle, observing deep silence, and with open mouths, and eyes glistening with delight, they anxiously await their turn. The chief man usually has the honour of enjoying the first pull at the pipe. From the moment that the orifice of the horn is applied to his lips, he seems to lose all consciousness of everything around him. He *swallows* the smoke. As little or no smoke escapes from his mouth, the effect is soon apparent. His features become contorted, his eyes glassy and vacant, his mouth covered with froth, his whole body convulsed, and in a few seconds he is prostrate on the ground. A little water is then thrown over him, proceeding not unfrequently from the mouth of a friend; his hair is violently pulled, or his head unceremoniously thumped with the hand. These somewhat disagreeable applications usually have the effect of restoring him in a few minutes. Cases are, however, known where people have died on the spot."

5°. Chemical Constituents of Tobacco.—The active substances or chemical ingredients of tobacco or of tobacco-smoke, those by which all its varied effects are produced, are four or five in number: a volatile oil, and a volatile alkali, which exist in the natural leaf: one or two volatile alkalies produced from this natural alkali; and an empyreumatic oil, which is formed during the burning of the tobacco in the pipe.

a. The volatile oil.—When the leaves of tobacco are mixed with water and submitted to distillation, a volatile oil or fat comes over in small quantity. This fatty substance congeals or becomes solid, and floats on the surface of the water which distils over along with it. It has the odour of tobacco, and possesses a bitter taste. On the mouth and throat it produces a sensation similar to that caused by tobacco-smoke. When applied to the nose, it occasions sneezing; and when taken internally, it gives rise to giddiness, nausea, and an

inclination to vomit. It is evidently one of the ingredients, therefore, to which the usual effects of tobacco are owing; and yet it is remarkable, that from a pound of leaves only two grains of this fatty body are obtained by distillation. Upon such minute quantities of chemical ingredients do the peculiar action and sensible properties of some of our most powerful medicinal agents depend!

b. The volatile alkalies.—When tobacco-leaves are infused in water made slightly sour by sulphuric acid, and the infusion is subsequently distilled with quicklime, there comes over mixed with the water a small quantity of a volatile, oily, colourless, alkaline liquid, which is heavier than water, and to which the name of *nicotine* has been given. It has the odour of tobacco—an acrid, burning, long-continuing tobacco taste—and possesses narcotic and very poisonous qualities. In this latter respect it is scarcely inferior to prussic acid, a single drop being sufficient to kill a dog. Its vapour is so irritating that it is difficult to breathe in a room in which a single drop has been evaporated. Nicotine, taken internally, in very small doses, produces general muscular excitement, copious secretions of gastric juice, diarrhœa, and sickness. The proportion of this substance contained in the dry leaf of tobacco varies from 2 to 8 per cent.[1]

So far as experiments have been made, the tobaccos of Havannah and Maryland contain 2 per cent, that of Kentucky 6, that of Virginia nearly 7, and that of France from 2½ to 8 per cent. It is rare, however, that 100 lb. of the dry leaf yield more than 7 lb. of nicotine. In smoking tobacco, however, a good deal of the active nicotine is changed into other alkalies, such as pyridine and picoline. These are poisonous also, but not so virulent as the natural base. Still, from a hundred grains of tobacco—say a quarter of an ounce—there *may* be drawn into the mouth two grains or more of nicotine, and of the two other poisons we have named. The nicotine boils at 468° F., the pyridine at 243°, and the picoline at 275°; so that, as all rise into vapour at a temperature considerably below that of burning tobacco, these poisonous substances are constantly present in the smoke. The propor-

[1] The reader may recollect the great sensation produced in 1851 by the trial of the Comte de Bocarmé at Mons, and his subsequent execution, for poisoning his brother-in-law with nicotine.

tion will vary with the variety of tobacco, the rapidity of the burning, the form and length of the pipe, the material of which it is made, and with many other circumstances. In manufactured tobacco, the French (1878) official returns give the nicotine as amounting to the following percentages:—

Tobaccos.	Per cent of nicotine.
Scaferlati,	1.8 to 2.5
Cheap cigars,	1.5 ,, 1.8
Havannah,	1.8 ,, 2.5
Snuff,	2.0 ,, 3.0

c. The empyreumatic oil.—But besides the two volatile substances which exist ready formed in the tobacco-leaf, another substance of an oily nature is produced when tobacco is distilled dry and alone in a retort, or is burned as we do it in a tobacco-pipe. This oil resembles one which is obtained in a similar way from the leaf of the poisonous foxglove (*Digitalis purpurea*). It is acrid and disagreeable to the taste, narcotic and poisonous. One drop applied to the tongue of a cat brought on convulsions, and in two minutes occasioned death. The Hottentots are said to kill snakes by putting a drop of it on their tongues. Under its influence the reptiles die as instantaneously as if killed by an electric shock. It appears to act nearly in the same way as prussic acid. The natives of Cambambe on the west coast of Africa poison the chameleon in a few seconds, by drawing a straw dipped in the "oil of pipes" across the poor creature's tongue and mouth.

The oil thus obtained consists of at least two substances. If it be washed with acetic acid (vinegar), it loses its poisonous quality. It contains, therefore, a harmless oil, and a poisonous alkaline substance, which the acetic acid combines with and removes. This poison contains the two liquid and volatile alkalies, pyridine and picoline, before named. The same liquids have been obtained from peat, shale, and coal. The crude oil is supposed to be the "juice of cursed hebenon," described by Shakespeare as a distilment.[1]

[1] The effects, real or imaginary, of this "juice" are thus described:—

"Sleeping within mine orchard,
My custom always of the afternoon,
Upon my secure hour thy uncle stole,
With juice of cursed hebenon in a vial,
And in the porches of mine ears did pour

Thus at least four active chemical substances unite their influences to produce the sensible effects which are experienced during the smoking of tobacco. All are contained in variable proportions in the smoke of burning tobacco. The form and construction of the pipe, among other circumstances, influence, as I have said, the proportion of these ingredients which the smoke contains. Thus the Turkish[1] and Indian pipes, in which the leaf burns slowly, and the smoke is made to pass gently bubbling through water, arrest a large proportion of the poisonous vapours, and convey the smoky air in a much milder form to the mouth. The reservoir of the German pipe retains the grosser portions of the oily and other products of the burning tobacco, and the long stem of the small Russian pipe has a similar effect. The Dutch and English clay pipes retain less; the metal (bronze or iron) pipes of Thibet (fig. 49), by becoming warm, bring still more of the constituents of the mild Chinese tobacco to the mouth of the smoker; while the cigar discharges much of its active constituents and products into the air. Cigars are generally made of such strong tobacco, that they produce, when in a pipe, a far greater degree of nausea and intoxication than when consumed in the proper way. Thus, the more rapidly the leaf

Fig. 49.

Thibet pipe, tobacco-pouch, and steel. The pipe is of brass or iron, often with an agate, amber, or bamboo mouthpiece.

The leperous distilment; whose effect
Holds such an enmity with blood of man,
That swift as quicksilver it courses through
The natural gates and alleys of the body;
And with a sudden vigour it doth posset
And curd, like eager droppings into milk,
The thin and wholesome blood: so did it mine;
And a most instant tetter bark'd about,
Most lazar-like, with vile and loathsome crust,
All my smooth body."—*Hamlet*, Act I. scene v.

[1] A collection of pipes worth £6000 is no unusual thing with high official and rich private persons in Constantinople. Amber mouthpieces, mounted with gold and jewels, and stems of cherry-wood, with unbroken bark, or of jasmine, with regular knots, are highly esteemed.

burns and the smoke is inhaled, the greater the proportion of the poisonous substances which is drawn into the mouth. That the smoke does intoxicate is shown by a peculiar way of using tobacco practised in Hawai. The natives swallow tobacco-smoke to produce intoxication: one pipe or a single cigar used in this way sufficing for a large company, each swallowing a whiff in quick succession. And finally, when the saliva is retained, the fullest effect of all the three narcotic ingredients of the smoke will be produced upon the nervous system of the smoker. Those who have been accustomed to smoke cigars of strong tobacco, find any other pipe both tame and tasteless except the short black *cutty*, which has lately come into favour again among inveterate smokers. Such persons live in an almost constant state of narcotism or narcotic drunkenness, which must ultimately affect the health, even of the strongest. It is a singular circumstance that the Mograbins of northern Africa chew natron, the native carbonate of soda, with their tobacco: and that the blacks of Gesira make a cold infusion of natron and tobacco, with a mouthful of which they delight to rinse their mouths for a quarter of an hour and then reject it. Is this custom of chewing soda with tobacco an imitation of the betel and lime used by the Indian traders to the African ports of the Red Sea? or is the origin of both customs to be found in the abundance of natron about the soda-lakes of Egypt and elsewhere in northern Africa? In either case it is equally remarkable that the practice of mixing an alkali with a narcotic should prevail in many different places, including even the Andes of Peru. Chemically, we know that the action of soda and of lime is literally the active ingredient of the plant, whether tobacco or coca. The chewer of tobacco, it will be understood, from the above description, does not experience the effects of the poisonous oil which is produced during the burning of the leaf. The natural volatile oil and the nicotine are the substances which act upon him. These, from the quantity of them which he involuntarily swallows or absorbs, impair his appetite, and gradually weaken his powers of digestion.

The same remarks apply to the taker of snuff. But his drug is still milder than that of the chewer. During the first fermentation which the leaf undergoes in preparing it for the manufacture of snuff, and again during the second fermenta-

tion, after it is ground, a large proportion of the nicotine escapes or is decomposed. The ammonia produced during these fermentations is partly the result of this decomposition.[1] Further, the artificial drying or roasting to which tobacco is exposed in fitting it for the dry snuffs, expels a portion of the natural volatile oil, as well as an additional portion of the natural volatile alkali or nicotine. Manufactured snuff, therefore, as it is drawn up into the nose, and especially dried snuff, is much less rich in active ingredients than the natural leaf. Even the rappees, though generally made from the strongest Virginian and European tobaccos containing 5 or 6 per cent of nicotine, retain only 2 per cent when fully manufactured. In the French Exposition of 1878, the following official figures were given as representing the percentage proportion of the various organic or combustible ingredients of French tobacco leaves unfermented:—

Nicotine,	1.5 to 9
Malic and citric acids,	10 ,, 14
Oxalic acid,	1 ,, 2
Pectose,	... 5
Cellulose,	7 ,, 8
Resin,	4 ,, 6
Nitrogenous matters,	... 25

I have already stated that in all the sensible properties by which the unadulterated leaf of the tobacco plant is characterised, the produce of different countries and districts exhibits important economical differences. All such diversities in quality and flavour, in strength, mildness, odour, &c., the chemist explains by the presence of the above-named active ingredients, sometimes in greater and sometimes in smaller proportion; and it is interesting to find science in his hands first rendering satisfactory reasons for the long-established decisions of taste. Thus he has shown that the natural volatile oil does not exist in the green leaf, but is formed during the drying; hence the reason why the mode of drying and curing affects the strength and quality of the dried leaf. He has also shown that the proportion of the poisonous nicotine

[1] Nicotine is one of those powerful vegetable principles which, like the *theine* of tea and coffee, are rich in nitrogen. Of this element it contains 17½ per cent. It is from this nitrogen that the ammonia is formed during the decomposition described in the text.

is smallest in the best Havannah, and largest in the Virginian and coarser French tobaccos. Hence a natural and sound reason for the preference given to the former by the smokers of cigars. And lastly, by showing that both of the active ingredients of tobacco are volatile, and tend to escape slowly into the air, he has explained why the preserved leaf, or the manufactured cigar, becomes of more refined flavour by keeping, and, like good wine, increases in value by increase of age.

As to the lesser niceties of flavour, by which certain samples of tobacco are distinguished, these probably depend upon the presence of other odoriferous ingredients, not so active in their nature, or so essential to the leaf as those already mentioned. The leaves of plants, in respect of their odours, are easily affected by a variety of circumstances, and especially by the nature of the soil they grow in, and of the manures applied to them. Even to the grosser senses and less minute observation of Europeans, it is known, for example, that pig's dung carries its *goût* into the tobacco raised by its means. But the more refined organs and nicer appreciation of the Druses and Maronites of Mount Lebanon readily recognise by the flavour of their tobacco the variety of manure employed in its cultivation. Hence, among the mountains of Syria, and in other parts of the East, those samples of tobacco are held in the highest esteem which have been aided in their growth by the droppings of the goat.

6°. Adulterations of Tobacco.—But in countries where high duties upon tobacco hold out a temptation to fraud, artificial flavours are given by various forms of adulteration. Sugar in some form or other is a very favourite material for this purpose, and molasses, treacle, and liquorice are all used. Gum, dextrine, common salt, green vitriol, and saltpetre, with various mineral and vegetable colouring matters, have been detected from time to time in different samples. The leaves of other plants dried and then flavoured with tobacco extract are not unfrequently found in manufactured tobaccos. Beet leaves, and those of rhubarb, dock, burdock, coltsfoot, and cabbage, are the most common. Is it surprising, therefore, that we should meet with manufactured tobacco possessing a thousand different flavours for which the chemistry of the natural leaf can in no way account?

Snuff has its own special adulterations, among which hellebore, to provoke sneezing, is the most deadly. Others are ground dyewoods, as Brazil wood, logwood, and fustic; ochre, red-lead, and ground peat; starches and meals; ground oak-bark and roasted acorns.

As substitutes for, or admixtures with tobacco, the leaves of different species of rhubarb, large and small, are collected in Thibet and on the slopes of the Himalaya. The long leaves of a Tupistra, called *Purphiok*, which yield a sweet juice, are also gathered in Sikkim, chopped up and mixed with the tobacco for the hookah—(Dr HOOKER). Other substitutes for genuine tobacco have been adopted in other countries, either from poverty or from taste. As a substitute for tobacco-snuff, the powdered rusty leaves of the *Rhododendron campanulatum* are used in India, and in the United States of North America the brown dust which adheres to the petioles of the kalmias and rhododendrons. All these plants possess narcotic qualities. The Otomacs, a tribe of clay-eaters in South America, also make a kind of snuff from the powdered pods of the *Acacia niopo*. This snuff throws them into a state of intoxication bordering on madness, which lasts for several days. While under its influence the cares and restraints of life are forgotten, and dreadful crimes are perpetrated.

7°. TOBACCO AN EXHAUSTING CROP.—One other point in the chemical history of tobacco, though not connected with its narcotic influence upon the system, it may be proper here to notice. I have elsewhere explained[1] that, when vegetable substances are burned in the open air, they leave unconsumed a portion of mineral matter or ash. The leaves of plants are especially rich in this incombustible ash, and those of tobacco are among the richest in this respect among cultivated leaves. The dried tobacco-leaf, when burned, yields from 11 to 28 per cent of ash; or, on an average, every 4 lb. of perfectly dry tobacco contains 1 lb. of mineral or incombustible matter. It is this which forms the ashes of our tobacco-pipes and of our burning cigars.

It is unnecessary here to describe in detail the composition of this ash, but I may remind my reader that all the substances it contains have been derived from the soil on which the tobacco plant was grown, and that they belong to the

[1] See the "Plant we Rear."

class of bodies which are at once most necessary to vegetation and least abundant even in fertile soils. In proportion, therefore, to the weight of leaves gathered must have been the weight of these substances withdrawn from the soil. And as every ton of perfectly dry leaves carries off four to five hundredweight of this mineral matter—as much as is contained in fourteen tons of the grain of wheat—it will readily appear even to those who are least familiar with agricultural operations, that the growing of tobacco must be a very exhaustive kind of cultivation. He will see in this, also, one main reason why tobacco plantations have in past times gradually become so exhausted as to be incapable, in many instances, of being longer cultivated with a profit—why once fertile lands are now to be seen lying waste and deserted—and why the fortunes of tobacco-planters, even in naturally favoured regions, have gradually declined with the failing fertility of their wearing-out plantations. Upon the Atlantic borders of the United States of America the best-known modern instances of the effects of this exhausting tobacco-culture are to be found. It is one of the triumphs of the chemistry of the present century, that it has ascertained what the land loses by such imprudent treatment, whatever crop is grown—what is the cause, therefore, of the barrenness which befalls it—by what new management its ancient fertility may be restored, and thus how new fortunes may be extracted from the same old soil.[1] But the immense quantity of nitrogen existing in the nicotine and nitre of tobacco, must not be left out of our calculations when considering the exhaustion of soil caused by this crop. The nitrogen is not left in the ash, but escapes during burning. It is a constituent of tobacco, requiring continual renewal in the soil under this crop.

[1] See the Author's Lectures on Agricultural Chemistry and Geology, 2d edition, p. 644.

CHAPTER XVI.

THE NARCOTICS WE INDULGE IN.

THE HOP, AND ITS SUBSTITUTES.

The hop: whence derived.—When brought to England.—Consumption in the United Kingdom.—Produce of Belgium.—Importance of the hop.—Beauty of the hop-grounds.—Management of the plant.—Properties which recommend its use in beer.—Varieties of the hop cultivated in England.—Qualities of the Farnham, Kent, North Clay, and Worcester hops.—Differences in estimation and flavour.—Soils on which they grow.—Chemical constituents of the hop-flower.—The oil of hops.—The aromatic resin.—The lupuline grains.—The bitter principle.—Physiological action of the hop.—Difference between ale and beer —Bitter substances used instead of the hop.—Cocculus indicus.—Singular qualities of this berry: its use in adulterating beer.—Poisonous picrotoxin contained in it.—Narcotic substitutes for the hop in South America, in India, and in China.—The Heetoo, Keesho, and Taddo of Abyssinia.—The marsh ledum used in Northern Europe.—Use of the yarrow, clary, and saffron.

II. The Hop—which may now be called the English narcotic—was introduced into this country at a comparatively recent period. It may have been employed in Germany in the times of the Roman writers, but was probably unknown to them. Its use, as an addition to malt-liquor, appears to be of German origin. Hop-gardens, by the name of Humolariæ, are spoken of in documents of the early part of the ninth century, and frequently in those of the thirteenth century. Into the breweries of the Netherlands the hop seems to have been introduced about the beginning of the fourteenth century. From the Low Countries, or, as some say, from Artois, which borders upon them, it was brought to England in the reign of

Henry VIII., some time after his expedition against Tournay, and about the year 1524. In the twenty-second year of his reign (1530), that monarch, in an order respecting the servants of his household, forbade sulphur[1] and hops to be used by the brewers. Three quarters of a century later (1603) the introduction of spoilt and adulterated hops was forbidden by James I. under severe penalties. This appears to show that, though considerable attention is known to have been already given to the cultivation of the hop in England, a large part of the hops supplied to the home market was still brought from abroad. In books of the sixteenth century, Kent was already called the county of hops.

1°. Consumption of the Hop.—At present the hops consumed in the United Kingdom are partly of home and partly of foreign growth, and the consumption is very great. Of hops of foreign growth, there were imported into the United Kingdom in 1876:—

United States, ...	67,752 cwt.	£311,816
Belgium, ...	46,543 ,,	208,630
Germany, ...	40,761 ,,	189,922
Holland, ...	9,541 ,,	40,015
France, ...	2,021 ,,	9,718
Other countries, ...	748 ,,	3,330

The exports of British hops are not considerable, while those of foreign hops are quite trifling.

It has been estimated that nearly one-third of all the hops grown in the world is consumed in Great Britain. How different a taste does this large consumption argue now from what must have prevailed in the beginning of the seventeenth century, when the city of London petitioned Parliament against two nuisances,—against Newcastle coals in regard of their stench, and against hops in regard they would spoil the taste of drink and endanger the people![2]

But Germany has a larger acreage under hops than England, and its average production is likewise greater—probably 30 per cent more. And the cultivation of this plant has extended to the American continent and to Australia. About 22,000 acres are devoted to it in the United States and

[1] This probably refers to the practice, which still prevails, of whitening or bleaching hops with fumes of sulphur, and which may not then have been so skilfully conducted as it is now.

[2] See Walter Blith's English Improver Improved, 3d edition, 1653.

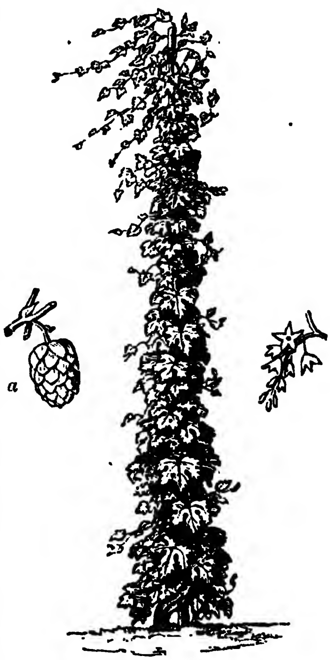
Canada; and nearly 1000 in New Zealand, Tasmania, and Victoria.

The importance of the hop among narcotics may be judged of by comparing its home consumption with that of tobacco:—

Hops, average consumption, . . .	590,000 cwt.
Tobacco in 1876, ...	455,300 ,,

Still, while all the above tobacco is consumed in this country, a considerable amount of the beer brewed in the United Kingdom is exported to foreign countries and colonies, and so the hops used in manufacturing it should be deducted. If 600,000 barrels be exported in a year, this would involve the use of at least 11,000 cwt. of hops.

Fig. 50.



Humulus Lupulus—The Hop plant.
a Female cone; *b* Male flower.

And who that has visited the hop-grounds of Kent and Surrey in the flowering season will ever forget the beauty and grace of this charming plant? Climbing the tall poles, and circling them with its clasping tendrils, it hides the formality and stiffness of the tree that supports it among the exuberant profusion of its clustering flowers. Waving and drooping in easy motion with every tiny breath that stirs them, and hanging in curved wreaths from pole to pole, the hop-bines dance and glitter beneath the bright English sun—the picture of a true English vineyard, which neither the Rhine nor the Rhone can equal, and only Italy, where her vines climb the freest, can surpass.

2°. Cultivation of the Hop.—The hop "joyeth in a fat and fruitful ground," as old Gerard wrote in 1596: "it prospereth the better by manuring." And few spots surpass, either in natural fertility or in artificial rich-

ness, the hop-lands of Surrey, which lie along the outcrop of what are called the greensand measures in the neighbourhood of Farnham. Naturally rich to an extraordinary degree in the mineral food of plants, the soils in this locality have been famed for upwards of two centuries for the growth of hops; and with a view to this culture alone, the best portions have sold as high as £500 an acre. And the *highest* Scotch farmer—the most liberal of manure—will find himself outdone by the hop-growers of Kent and Surrey. An average expenditure of £10 sterling an acre for manure over 100 acres of hops, farmed by a single individual, makes this branch of farming the most liberal, the most remarkable, and the most expensive of any in England. It is remarkable that on the introduction of guano and superphosphate about 1841-43, the average yield of hops per acre took a sudden upward jump, which it has maintained ever since. Shoddy and other wool-waste, as well as rape-cake, are now largely used as hop-manure. Hops are grown in fifteen counties of England, but the acreage under this plant is insignificant except in Kent, Sussex, Herefordshire, Hampshire, Worcestershire, and Surrey. The total number of acres now (1878) devoted to this crop is 71,789, an increase of 550 acres over the preceding year. The following table shows the number of acres of hops in the six hop-growing counties, with the percentage of such acreage to all the land under hops in England:—

Counties.	Acres of hops, 1878.	Percentage of all English hop-land.
Kent,	46,593	64.9
Sussex,	10,991	15.3
Hereford,	5,947	8.3
Hampshire,	3,190	4.4
Worcestershire,	2,474	3.4
Surrey,	2,305	3.3
Shropshire, and 9 others,	289	0.4
	71,789	100.0

The mode of managing the hop, and the peculiar value and rarity of hop-land, were known very early. They form parts of its history which were probably imported with the plant itself. Tusser, who lived in Henry VIII.'s time, and in the reigns of his three children, in his 'Points of Husbandry,' thus speaks of the hop:—

"Choose soil for the hop of the rottenest mould,
Well-doonged and wrought as a garden-plot should:
Not far from the water (but not overfloune),
This lesson well noted, is meet to be knowne.

The sun in the south, or else southlie and west,
Is joy to the hop as welcommed ghest;
But wind in the north, or else northerly east,
To hop is as ill as fray in a feast.

Meet plot for a hop-yard, once found as is told,
Make thereof account as of jewel of gold;
Now dig it and leave it, the sun for to burne,
And afterwards fense it, to serve for that turne.

The hop for his profit, I thus do exalt:
It strengtheneth drink, and favoureth malt;
And being well brewed, long kep it will last,
And drawing abide, if ye draw not too fast." [1]

3°. USES OF THE HOP.—The hops of commerce consist of the female flower and seeds of the *Humulus Lupulus*, or common hop plant (fig. 51). Their principal consumption is in the manufacture of beer, and they possess three properties which particularly fit them for this use. First, They impart to malt-liquors a pleasant, bitter, aromatic flavour and tonic properties. Second, They give them a peculiar *headiness*, often confounded with alcoholic strength, and thus save to the brewer a certain proportion of his malt. The soporific quality of beer, also, is ascribed in part to the narcotic quality of the hop. Third, by their chemical influence they clarify malt-liquors, and check their tendency to become sour. They arrest the fermentation at the alcoholic stage; and it appears from the history of the art of brewing, that beer which could be kept for a length of time has only been manufactured in England since the hop has been introduced. "The ale," says Parkinson (1640), "which our forefathers were accustomed only to drink being a kind of thicker drink than beere, is now almost quite left off to be made, the use of hoppes to be put therein altering the quality thereof, to be much more healthful or rather physicall, to preserve the body from the repletion of grosse humours which the ale engendereth."

4°. VARIETIES OF THE HOP.—Of the cultivated hop there are many varieties; but in our principal English hop-districts, Kent, Surrey, and Sussex, only about five varieties are exten-

[1] Five Hundred Points of Good Husbandry. London edition of 1812, p. 167.

sively grown. These sometimes go under different names in different districts, while other varieties (as Mathon's and Cooper's) are now grown. The five oldest sorts are—

First, The *goldings*, grown chiefly in middle and east Kent, but to an increasing extent in other hop-districts. They grow to a great height, requiring poles 15 feet high. They delight in a rocky calcareous soil or a rich friable loam. They thrive only in the most naturally fertile kinds of soil.

Fig. 51.

Humulus Lupulus—The Common Hop. The upper is the male plant and flower; the lower figure is the female flower.

Second, The *white-bines* are the favourites of Farnham and Canterbury. They require the same description of soil as the goldings, are very similar in their appearance and growth, and have nearly the same value in the market. The flower of the white-bines is considered to possess the more delicate flavour, while that of the goldings is thought by some brewers to have more strength.

These two varieties are most esteemed for the brewing of pale bitter ale. They both require very long poles, and on the average of years produce smaller crops than the coarser kind of hop.

Third, The *Jones's* stand next in favour with the brewer. They will grow on inferior land; and as they require very short poles, and are pretty good croppers, they are in general favour with many growers in Kent.

Fourth, The *grape* has many sub-varieties, and requires longer poles than the Jones's. This variety delights in stiff heavy soils, after thorough drainage, and produces very heavy crops. Hence its prevalence in the Weald. It is commonly used for the ordinary sorts of beer.

Fifth, The *colegate* is a smaller variety of hop than the

grape, but produces enormous crops in Sussex and the Weald of Kent. It is often surreptitiously passed off in the market as goldings; but it is greatly disliked by the brewers on account of the rankness of its flavour. It is looked on by many as the worst hop that is grown.

From the kind of soil on which they grow, these two varieties are also known by the name of *clay hops*. Those which are raised in the Weald of Kent and Sussex, should, I suppose, be called *south clay hops*, as those which grow on the stiff clays of Nottinghamshire are known in the market as the *north clays*.

From this brief description of the more common varieties of this plant, it will be understood that a great diversity of flavour and quality must prevail among the hops, not only of different districts, but even of the same county. Thus the county of Kent produces hops of various degrees of excellence, the best samples combining in an eminent degree the qualities of flavour and strength. The soils of this county rest chiefly on the chalk, but partly also, on its south-west border, on the greensand formation. Its northern part is covered by the tertiary beds of the London basin; and it is around Rochester and Canterbury, where the clays of these tertiaries and the porous chalks meet, that the best Kent hops are grown. Inferior samples grow on the clays of the Kentish Weald.

In Surrey, again, the hops of the neighbourhood of Farnham have from time immemorial borne the highest price in the British hop-market. They grow on the marly soils rich in phosphate of lime, which are formed from the rocks of the greensand formation; and so much does their excellence depend upon the natural quality of the soil, that the value of the crop changes sometimes on the mere crossing of a hedge. The change of quality in the soil in this locality is often sharp and sudden, and hence the equally sudden change in the quality of the crops it produces.

The clay hops of Kent and Sussex are coarse and rank, but those of the small district of Retford in Nottinghamshire, called the *north clays*, are pre-eminent in rankness. They give a coarse flavour to beer, which is very disagreeable to those who are unaccustomed to it. The stiff clays of the county of Nottingham, on which these hops grow, lie in the

valley of the Trent, and are formed chiefly from the *débris* of the new red sandstone, through which the Trent flows, with admixtures from the coal-measures, magnesian limestone, and lias clay brought down by the feeders of the Trent. Probably a more thorough drainage of this district would improve the quality of its hops, to which, indeed, now but a few acres are devoted.

To those who are accustomed to the mild flavour of the Kent hops, that of the north clays is almost nauseous. But the Kent hops, again, are disrelished by those who have been accustomed to the still milder flavour of the Worcester hops. These excel in this respect the best Kent goldings, and are usually very taking to the eye. In practice, they are found to ripen beer sooner than any other variety of hop. They grow on the red soils of the valleys of the Severn and the Teme, and, in the opinion of beer-drinkers, possess a grateful mildness not to be found in any other hops. Hence, in Lancashire, Cheshire, and some other counties, where the taste for the Worcester hops exists, even fine Kent hops would be rejected as unsaleable. A nice Lancashire beer-drinker calls beer hopped with Kent hops *porter ale.* They do not answer, however, for the best descriptions of malt-liquor, such as the pale ale, because they do not impart so fully the keeping quality.

The red soils of Worcestershire are formed from the *débris* of the new red sandstone, sifted and sorted by the waters of the Severn. The traveller passes through part of this hop-region on his way from Worcester to Malvern. The red soils of Hereford, on which also hops are largely grown, are derived from the old red sandstone, and in mildness of quality the hops they yield are, I believe, similar to those of Worcester. Rich, open, and friable, these red soils so far resemble those of Kent and Surrey, from which the Canterbury and Farnham hops are gathered. The variety of hop grown in this region differs, however, from those of Kent and Surrey. It is supposed to be a descendant of the Flemish red-bine.

That different samples of hops, both home-grown and foreign, differ greatly in quality even when of the same year's growth, may be gathered from their market prices. This may range from £2 or £3 per cwt., up to £8 or £10, or even more. Thus the soil or locality in which they are grown, and the

variety raised, have much influence upon the flavour which the hops will impart to beer. But besides these, the time of picking, the mode of drying and curing, the care bestowed on the bagging, the place in which they are afterwards kept, and the length of time they have been gathered, all affect the finer qualities of the hop-flower. And if to these we add the numerous minute variations which occur in the process of brewing, from time to time, even in the same establishment, it will no longer appear surprising that a very great variety of flavours should be given to beer by the use of hops alone.

5°. Active ingredients of the Hop.—In so far as such diversities of flavour depend upon the quality of the hop itself—and not upon the quality of the water employed, which much affects the flavour of beer—they are probably due, as in the case of tobacco, to the different proportions in which the active chemical ingredients of the flower exist in the several samples. These active ingredients, in so far as is yet known, are three in number—a volatile oil, a slightly aromatic resin, and a bitter principle.

a. The volatile oil.—When hop-flowers are distilled with water, they yield a volatile oil. This oil has a brownish-yellow colour, a strong smell of hops, and a slightly bitter taste. In this oil of hops a portion of the narcotic influence of the flower resides. It consists of at least two oils—one a kind of turpentine, the other related to valerianic acid, the acid of valerian.

The hop has long been celebrated for its sleep-giving qualities. To the weary and wakeful the hop-pillow has often given refreshing rest, when every other sleep-producer had failed. It is to the escape of the volatile narcotic ingredients above mentioned, in minute quantity from the flowers, that this soporific effect of the hop is most probably to be ascribed. Various medicinal preparations of this plant have been lately introduced. The volatile oil is extracted from the flowers by means of ether, petroleum spirit, or bisulphide of carbon, and then the solvent used is cautiously removed by evaporation. A solution of the oil in glycerine has also been prepared for medicinal purposes.

Upon the same volatile ingredients depends the odour which is perceived in store-rooms where hops are kept, and much of the aroma they impart to beer. It is owing to the

escape of this ingredient, even from the most closely pressed hops; that they deteriorate in quality so much by keeping, as usually to fall one-third in value when upwards of a year old. By boiling in the wort, also, a portion of the same delicate aromatic principle is driven off and lost to the beer.

b. The aromatic resin.—When dry hop-flowers are beaten, rubbed, ~~and sifted~~, a fine yellow dust separates from them, which is equal in weight to about a sixth part of that of the hops. This fine powder is sometimes distinguished by the name of *lupulin.* Hop-buyers talk of it as the "condition" of the hop. Under the microscope the powder is seen to consist of minute, somewhat transparent, grains or glands of a rounded form, a golden-yellow colour, and a cellular texture. By drying they lose their round form (see fig. 52), and when put into water they give out an immense number of minute globules. The function of these organised lupulinic glands, as a part of the plant, is involved in much obscurity. They possess a strong agreeable odour, and a bitter taste. When taken internally, they are aromatic and tonic. They soothe, also, and tranquillise, allay pain, reduce the pulse, and in a slight degree provoke sleep. Alcohol dissolves out from them much reddish-yellow transparent resin, which is slightly aromatic, but when pure is not at all bitter. This is the aromatic resin of the hop-flower, of which it forms one-twelfth part, or 8 per cent by weight. What share this resin has in producing the effects which follow from swallowing the entire grains, is not satisfactorily known.

Fig. 52.

Dried lupulin-gland, greatly magnified.

c. The bitter principle.—Besides the resin of hops, and about 2 per cent of volatile oil, 4 per cent of tannin, and a peculiar bitter principle are also present. This last is the best-known constituent of the hop, and gives bitterness to our beers. The tannin helps to clarify the beer.

But though the specific action of each of the chemical principles contained in the hop-flower has not been very well ascertained, and although some of them have probably escaped detection, yet the united action of all of them together is well known. The tinctures and extracts of hops which we use in medicine, and introduce into our beers, contain them all, so that all the virtue of the hop, in whichever of the ingredients

it resides, is present in them in a greater or less degree. Hence well-hopped beer is aromatic, tonic, soothing, tranquillising, and in a slight degree narcotic, sedative, and provocative of sleep. The hop also aids in clarifying malt-liquors, arrests the fermentation before all the sugar is converted into alcohol, and thus enables them to be kept without turning sour.

Ale was the name given to unhopped malt-liquor before the use of hops was introduced. This is alluded to in the passage already quoted from Parkinson, and in the two old lines,—

> "*Hops*, reformation, bays, and *beer*,
> Came into England all in one year."

The words of Gerard, also, show the original meaning of the two words. "The manifold virtues in hops do manifestly argue the wholesomeness of *beer* above *ale;* for the hops rather make it physicall drinke, to keep the body in health, than an ordinary drinke for the quenching of our thirst." When hops were added, it was called beer by way of distinction; I suppose, because we imported the custom from the Low Countries, where the word beer was still in use.[1] Ground-ivy (*Nepeta Glechoma*), called also *alehoof* and *tunhoof*, was generally employed for preserving ale before the use of hops was known.

To the general reader it may appear remarkable—perhaps he may even think it a reproach to science—that the chemistry of a vegetable production in such extensive use as the

[1] This word is found both in the new and old dialects of the high and low German, Dutch, and Flemish, in the form of *bier*. In France it is *bière*, and in Italy *birra*. In these latter countries it has superseded the old word *cervoise*, still used in Languedoc; *cervogia*, still heard in Italy,—both of which, like the Spanish *cerveza*, are from the Latin *cervisia*, a word used by Pliny for a drink made from malt.

In Anglo-Saxon it was *beor;* in new and old Norsk, *bior;* in Gaelic, *beôir;* in Breton, *ber* or *bier;* and the Britons are said by Tacitus to have made a sort of wine from barley which they called *baer*.

But this word for the drink disappeared from England, and ale took its place, till it was brought in again to denote *hopped* ale, a sense which it did not originally bear. It disappeared also from the Welsh, whose name for beer is *cwrw*. But though it has penetrated into France and Italy, *öl* is still the only word in use in Scandinavia. This Scandinavian name, which prevailed among us after the Romans left, points, like so many other relics, to the race which has chiefly predominated in the island since.

hop should still be so imperfect, our knowledge of its nature and composition, and of the special physiological effects of its several constituents, so unsatisfactory. But the well-read chemist, who knows how wide the field of chemical research has become, how rapidly our knowledge of it as a whole is progressing, and who endeavours in his daily studies to keep up with that progress—he will feel no surprise. He must wish, indeed, to see all such obscurities and difficulties cleared away; but he will feel more inclined to thank and praise the many ardent and devoted men who in every country are now labouring in this department, and to encourage them in what they are doing, than to blame or reproach them for being obliged to leave a part of the extensive field for the present uncultivated.

The hop, as we have seen, is to be placed among the most largely used narcotics, especially in England. It differs, however, from tobacco, and the other favourite narcotics to be hereafter mentioned, in being rarely employed alone except medicinally. It is added to infusions like that of malt, to impart flavour, taste, and narcotic virtues. Used in this way it is unquestionably one of the sources of that pleasing excitement, gentle narcotic intoxication, and healthy tonic action which well-hopped beer is known to produce upon those whose constitutions enable them to drink it. Other common vegetable productions will give the bitter flavour to malt-liquors. Horehound, wormwood, gentian, quassia, camomile, fern-leaves of different species, broom-tops, ground-ivy, common gale, the bark of the box-tree, dandelion, chicory, orange-peas, picric acid, chiretta, and many other substances,[1] have been employed or recommended in England, to replace or supplant the use of the hop. But none of these approach it in imparting those peculiar properties which have given the English bitter beer of the present day its high reputation. It is to be deplored that brewers are allowed to substitute for the delightful aromatic bitter of the hop the clinging and sharp chiretta and quassia.

It is interesting to observe how men carry with them their early tastes to whatever new climate or region they go. The

[1] The notion that strychnine has ever been employed for giving bitterness to beer is entirely devoid of foundation. It is a deadly poison, though in small doses acting as a tonic. It is excessively bitter.

love of beer and hops has been planted by Englishmen in America. It has accompanied them to their new empires in Australia, New Zealand, and the Cape. In the hot East their home taste remains unquenched, and the pale ale of England follows them to remotest India. Who can tell to what extent the use of the hop may become naturalised, through their means, in these far-off regions? Inoculated into its milder influence, may not the devotees of opium and the intoxicating hemp be induced hereafter to abandon their hereditary drugs, and to substitute the foreign hop in their place? From such a change in one article of general consumption how great a change in the character and habits of the people might we not anticipate?

III. Cocculus Indicus can scarcely be classed among the narcotics in which we voluntarily indulge, but it is certain that it was used to some extent by small brewers and beer-sellers for the adulteration of beer a few years ago. If we may accept the results of the Inland Revenue investigations, the use of this poisonous and injurious narcotic bitter has been abandoned: it is to be hoped that it is so. It is the fruit or berry of the *Menispermum Cocculus* (fig. 53), a beautiful climbing-plant, which is a native of the Malabar coast and of the Indian Archipelago. It is sometimes called the Levant nut, or the *Bacca orientalis*. It has some resemblance to the

Fig. 53.

Menispermum Cocculus—The Cocculus indicus plant.

bay-berry, and in 1850 was imported into this country to the extent of 2359 bags, of 1 cwt. each. It is really wonderful in how many ways this singular substance is fitted to aid the dishonest brewer in saving both malt and hops. I mention three of its properties most tempting to the beer-adulterator.

If the bruised seeds are digested in water, they yield an extract which, when added to beer, produces the following effects :—

First, It imparts to it an intensely bitter taste, and can thus be substituted cheaply for about one-third of the usual quantity of hops, without materially affecting the flavour of the beer.

Secondly, It gives a *fulness* and richness in the mouth, and a darkness of colour, to weak and inferior liquors. In these respects, a pound of *Cocculus indicus* is said to be equivalent to a sack (four bushels) of malt. Or, to a thin brewing of beer, a pound of this drug will give an apparent substance equal to what would be produced by an additional sack of malt.

Thirdly, It produces upon those who drink it some of the symptoms of alcoholic intoxication, and thus adds to the apparent strength and inebriating quality of the liquor. Like hops, it also prevents second fermentation in bottled beer, and enables it to keep in warm climates.

This is a formidable array of tempting qualities. The use of this drug is forbidden by Act of Parliament, under a penalty of £200 to the brewer, and of £500 to the druggist who sells it to a brewer. But an extract is prepared and sold. Some writers on brewing give plain directions for using the drug; and the quantity recommended by Morrice to the honest brewer (!) is 3 lb. of *Cocculus indicus* to every 10 quarters of malt. By the dishonest it was said to be used to the extent of 1 lb. to the barrel of 54 gallons, with *Calamus aromaticus* and orris-root to flavour it. If 1 lb. really save 4 bushels of malt, the 2359 cwt. imported in 1850, if all employed for this purpose, must have saved to the adulterators who used it the enormous quantity of 1,056,000 bushels!

It is chiefly the humbler classes upon whom such a fraud as this could be practised. The middle classes in England prefer the thin wine-like ales and bitter beers. The skilled labourer prefers what is rich, full, and substantial in the

mouth; and the poor peasant, after his day's toil, likes to find at the bottom of his single pot what will sensibly affect his head. It is thus chiefly among the working men that the heavy drugged beer of the adulterator is relished and consumed.

The effects which this substance produces are said, by those who have drunk beer drugged with it, to be more upon "the voluntary muscles than upon the intellectual powers."[1] If so, a man under its influence may be surprised by finding his body helpless while his mind is comparatively clear, and still capable of reasoning and judging with tolerable correctness. Others say, however, that its effect is chiefly on the brain, so that its mode of action probably varies in some degree with the constitution of the individual who takes it.

In large doses it is poisonous to all animals, and a well-known use of it is for the stupefying of fish.[2] Although, therefore, its special effects upon the human constitution have not been accurately ascertained by scientific physiologists, the frequent use of *Cocculus indicus*, even in small doses, can scarcely fail sooner or later to injure the health.

This poisonous quality is derived chiefly from a white crystalline intensely bitter substance called *picrotoxin*, which exists in the inner portion of the berry. This body, unlike most active poisons, is destitute of nitrogen, containing only carbon, hydrogen, and oxygen. It dissolves in 150 parts of cold, and 25 of boiling water. It produces vertigo, convulsions, and death. The way in which this poisonous ingredient acts upon the system is still involved in considerable obscurity; but there cannot be a doubt as to the moral criminality of introducing substances of so dangerous a kind into the common drink of the least protected part of the people.

IV. Other substitutes for the Hop.—Other narcotic substances more or less powerful are in different countries substi-

[1] Pereira—Materia Medica, 3d edition, p. 2155.

[2] In India, the bruised leaves of *Phyllanthus conami*, and the capsules of the *Xanthophyllum hastile* (Lindley), and on the Himalayas the seeds of the Chaubmoogra, and the fruit of the evergreen Took, or Hydrocarpus, are used for intoxicating fish—(Hooker). The bruised root of the *Randia dumetorum* has a similar effect—(Roxburgh). I am not aware that any of these is ever administered to man. The Indians of South America use bruised Angostura bark to intoxicate fishes—(Hancock); and the Peruvians make the same use of Cinchona bark—(Saunders).

tuted occasionally for the hop. And, like *Cocculus indicus*, the most injurious of these substitutes are generally introduced into the liquor without the knowledge of the drinker. Thus—

1°. *In South America* the bitter stalks of the *Schinus molle* are mixed with the chica, which is prepared by chewing the sweet pods of the *Prosopis algaroba*.[1] What is the action of this bitter substance on the drinker of the chica is not stated. A mixture of black sugar and water, called *gcapa*, is made by the negroes of Brazil, and although unfermented, is drunk, on account of its cheapness, with avidity by both men and women, who continue whole days at it, dancing and singing. To give it an intoxicating effect the leaves of the *akajee* tree are added. The Portuguese make cider, as well as another drink called *kooi*, of the apple *akajee*, and also a sherbet of sugar, water, lemons, and nutmegs. Kooi is the pressed juice of the *akajee* apple, fermented.

2°. *In India*, when the raw cane-sugar (jaggery) is fermented with a view to the distillation of rum, chips of the dried bark of the *Acacia ferruginea* or *A. leucophlea*, are added to the liquor. It is supposed to act like hops in moderating the fermentation, and probably gives a flavour and other peculiar qualities to the rum distilled from it, but it is not known to be added with a view to any narcotic effects. The rum itself is described by Buchanan as being execrable.[2]

3°. *In China* a kind of beer, called *tar-asun*, is made from barley or wheat. In brewing this beer, a prepared hop is added to the wort, which both causes fermentation and performs at the same time the duties of the hop. Of what this preparation consists my authority does not say.[3]

4°. *In Africa.*—In preparing their hydromel, or mead, the Abyssinians add to the solution of honey a portion of a bark called *heetoo*. The leaves and fruit of the tree from which this bark is taken are narcotic and poisonous. It is probable, therefore, that the bark, which is described as bitter, astringent, and tonic, may also possess a portion of the same narcotic virtue, and impart it to the mead.

The leaves of a tree called *keesho* are likewise used in

[1] See "The Liquors we Ferment," p. 221.
[2] Journey through the Mysore, vol. i. p. 39.
[3] Morewood—On Inebriating Liquors, pp. 120, 175.

Abyssinia for mixing with mead,[1] but it is not stated if they possess narcotic properties. This is probably the Kousso or Kupo—*Brayera anthelmintica.* The dried flowers impart to water an acrid and bitter taste. They are probably infused in beer for the sake of their anthelmintic properties: the Abyssinians being peculiarly subject to worms. Other travellers speak of a root called *taddo* as being in common use among Ethiopian tribes, as an addition to the mixture of malted barley and honey of which their favourite drink is made. But nothing is known of the chemical history of these and the other substances.

5°. *In Northern Europe.*—The *Ledum palustre* (the marsh ledum, or wild rosemary), fig. 54, a heath-plant common in the north of Europe, allied to the Rhododendrons, was formerly used in Sweden and North Germany for giving bitterness and apparent strength to malt-liquors. Its leaves, when infused in the wort, render the beer unusually *heady*, so as to produce headaches, nausea, and even delirium, when drunk to excess. In Germany the use of it for this purpose is now forbidden by law.

Fig. 54.

Ledum palustre—The Marsh Ledum, or Labrador Tea. The undermost flower and leaf represent those of *Ledum latifolium*—The Labrador Tea, or broad-leaved Ledum.

Scale, 1 inch to 2 feet. Leaves and flowers nearly natural size.

The *Ledum latifolium* possesses similar narcotic properties, and, where it occurs in sufficient abundance, is used instead of, or along with, the *L. palustre.*

In North America, both these plants are known by the name of Labrador tea, and are used as substitutes for Chinese tea. Both are very astringent; and, in addition to the tannic acid to which this property is due, probably contain also a narcotic principle not yet examined. To this narcotic principle both the qualities which fit these plants to be used in cold climates as a substitute for tea, and those which enable it to impart intoxi-

[1] Harris's Highlands of Ethiopia.

cating properties to beer, are to be ascribed. According to Dr Richardson, the narrow-leaved *L. palustre* is the better suited of the two for the making of tea.[1] Both plants would probably well repay a detailed chemical examination.

The leaves of yarrow or millefoil (*Achillea Millefolium*) have the property of producing intoxication. These are also used in the north of Sweden by the Dalecarlians to give headiness to their beer.

6°. *In England*, clary (*Salvia sclarea*) is said to give an intoxicating quality to beer. Saffron also, the dried stigmas of the *Crocus sativus*, has a similar effect. It exercises a specific influence on the brain and nerves, and when taken in large doses, causes immoderate mirth and involuntary laughter. Its exhilarating qualities are so remarkable that it has been supposed to be the *nepenthes* of Homer; and to denote a merry temper it became a proverb, "Dormivit in sacco croci"—(he has slept in a saffron bag). It has the singular property, also, of counteracting the intoxication produced by alcoholic liquors, as hops to some extent do. This was known to Pliny, who says that it allays the fumes of wine and prevents drunkenness. "It was therefore taken in drink by great wine-bibbers, to enable them to drink largely without intoxication."[2] Its effects, however, are very uncertain, and it is now little used in medicine, and probably not at all for adulterating beer. It is still employed, especially in Cornwall, for colouring and flavouring cakes. But quassia-chips (the wood of *Picræna excelsa* chiefly, but perhaps of two or three different trees), as well as the roots and stems of *Ophelia chirata*, *O. angustifolia*, and *O. elegans*, known as chiretta or chirayta, are extensively used in England as substitutes for the bitter of the hop. Both quassia and chiretta appear to be tonic and not poisonous, but, like the buck-bean, they are not aromatic. Chiretta and buck-bean belong to the Gentian order.

[1] See "The Beverages we Infuse," p. 143.

[2] For much more on saffron, see Phillips's History of Cultivated Vegetables, vol. ii. p. 180.

CHAPTER XVII.

THE NARCOTICS WE INDULGE IN.

THE POPPY AND THE LETTUCE.

The poppy, ancient and modern use of.—Preparation of opium.—Mode of collecting.—How opium is used. —Effects of opium.—It sustains the strength. —Delightful reveries produced by. —De Quincey's experience; that of Dr Madden.—Final results of opium indulgence.—Seductive influence of opium.—Case of Coleridge.—Impotence of the will under its influence.—Difficulty of giving it up.—Bodily and mental tortures in doing so. —Extent to which opium is used.—Produce and consumption in India and China.—Consumption in Great Britain.—Its use as an indulgence in this country.—Drugging of children, and its effects.—Chemical constituents of opium.—Properties of morphine.—Little known of the true action of opium.—Average composition of opium.—Varieties in its strength.—Proposed opium-culture in France.—Influence of the variety of poppy on the proportion of morphine.—Morphine not so poisonous to inferior animals.—Dilution of opium in India and Java.—Influence of race in modifying the effects of opium.—The Javanese, the Malay, and the Negro.—Corrosive sublimate eaten with opium.—Effects of opium compared with those of wine. —Is opium necessarily deleterious?—Dr Eatwell's testimony.—Practical conclusions.—Substitutes for opium: Bull-hoof.—The lettuce, lactucarium and lactucin; resemblance to opium in properties and physiological effects.—Syrian or Steppe rue; its uses in the East as a narcotic indulgence.

V. The Poppy.—The use of the common white poppy (*Papaver somniferum*), fig. 55, as a soother of pain and a giver of sleep, has been familiar from the earliest periods. This is partly shown by the names—*poppy* in English and *papaver* in Latin—which are said to have been given to the plant be-

cause it was commonly mixed with the food of young children (pap or papa) to ease pain and secure sleep. In this country, the chief use of the poppy is as a medicine.

In the East, however, it is used as an exhilarating narcotic. The Tartars of the Caucasus, who, though professedly Mohammedans, drink wine publicly, make it very heady and inebriating by hanging the unripe heads of poppies in the casks while the fermentation is going on. A decoction of poppies also, called *kokemaar*, is sold in the coffee-houses of the Persian cities, where it is drunk scalding hot, and produces amusing effects. As it begins to operate, the drinkers quarrel with and abuse each other, but without coming to blows; and afterwards, as its effect increases, make peace again. One utters high-flown compliments, and another tells stories; but all are extremely ridiculous, both in their words and actions—(TAVERNIER).

Fig. 55.

Papaver somniferum—Common white Poppy. Scale, 1 inch to the foot.

1°. PREPARATION OF OPIUM.—But it is the dried or concrete juice of the poppy-head that is generally and extensively employed as a narcotic indulgence. This dried juice is called by the Persians *afioun*, and by the Arabs *afioum*, and hence our European name *opium*.

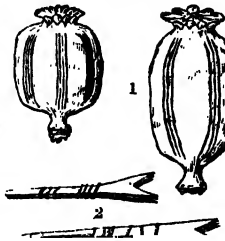
This important drug is obtained by making incisions into the capsules or seed-vessels of the poppy plant when they are nearly ripe, allowing the milky juice which exudes to thicken upon the capsules for twenty-four hours, and then scraping it off. In India the incisions are made downwards through the outer skin only: in Asia Minor the incisions are horizontal. For this purpose a small knife, called a Nushtur, is used, which consists of three or four minute blades, fastened together (fig. 56 2). These knives make as many parallel incisions, which allow the juice freely to escape.

The appearance of the poppy-fields in Bengal, and the way

in which the dried juice is collected by the natives, is represented in fig. 57.

The best opium of commerce is a soft unctuous mass, of a reddish or blackish-brown colour, a waxy lustre, a strong disagreeable odour, and a bitter, acrid, nauseous taste, which remains long in the mouth. It is chiefly collected in Asiatic Turkey, in Persia, and in India. The opium which comes from Smyrna is most esteemed in the European markets, while that which is produced in India is the most extensively used in Eastern countries. The greatest yield of good opium in our Indian possessions is stated to be 41 lb. per imperial acre, and the average to be 20 to 25 lb.

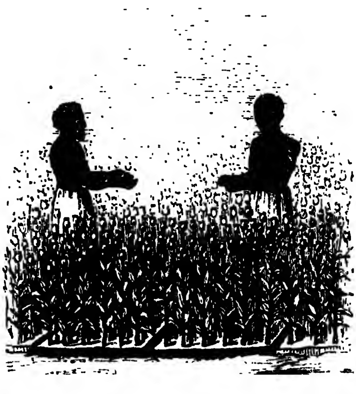
Fig. 56.



1. Poppy-heads, showing the parallel incisions.
2. Nushturs, or poppy-knives.

2°. How it is used.—As a narcotic indulgence, opium is used in one or other of three ways. It is swallowed in the solid state in the form of pills; or in that of fluid tinctures, such as our common laudanum; or it is smoked in minute pipes, after the manner of tobacco. The first practice prevails in Mohammedan countries, especially in Turkey and Persia; the second among Christian nations, when individuals happen to become addicted to the practice; the third in China and the islands of the Indian Archipelago. In preparing it for smoking, the Chinese extract from the Indian opium all that water will dissolve. This is generally from one-half to three-fourths of the whole weight. They then evaporate the dissolved extract to dryness, and make it into little pills. One of these

Fig. 57.

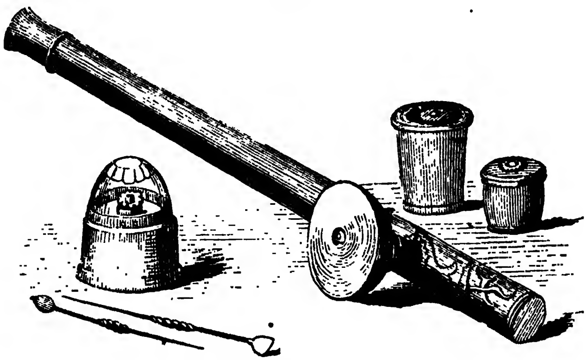


Indians scraping the dried juice from the poppy-heads.

they put into a short tiny pipe, often made of silver, inhale a few puffs at a time, or one single long puff, and return the smoke through the nostrils and ears. This they repeat till the necessary dose has been taken (fig. 58).

At Singapore, the mode of using it is much the same as in China. "The opium-shops," says Captain Wilkes, "are

Fig. 58.



Opium-box, pipe, lamp, and needle.

The needle is put through two holes on the opposite sides of the pipe, the pill is fixed on the middle of the needle, as seen in the figure, and immediately over the central hole of the pipe-bowl. The lamp is then applied, and the vapours sucked in.

among the most extraordinary sights in Singapore. It is inconceivable with what avidity the smokers seek this noxious drug at the shop-windows. They then retire to the interior, where a number of sickly-looking persons, in the last stage of consumption, haggard, and worn down with care, are seen smoking. The drug is sold in very small pieces, and for ten cents enough to fill a pipe once is obtained. With it are furnished a pipe, a lamp, and a couch to lie on, if such it may be called. The pipe is of a peculiar construction, and is in part of metal, having an interior or cup just large enough to contain a piece the size of a pea. The opium is difficult to ignite, and it requires much management in the smoker to obtain the necessary number of whiffs to produce intoxication in one habituated to its use. The couch is sometimes a rude bench, but more often a mat on the floor, with a small raised bench; and, in the frequented

shops, is generally occupied by a pair of smokers, who have a lamp between them."[1]

In Borneo, Sumatra, and Java, the extract is not evaporated to dryness; but, while still liquid, it is mixed with finely-chopped tobacco and betel till the whole is absorbed. This is then made up into pills about the size of a pea. At convivial parties a dish of these peas is brought in along with a lamp, when the host takes the pipe, puts in one of the pellets, takes two or three long whiffs, returning the smoke through his nostrils, and, if he be an adept, through his eyes and ears. He then passes the pipe round the company, each of whom does the same with the same pipe; and so they continue smoking till all are intoxicated.[2]

3°. Effects of Opium.—Used in any of the three ways I have mentioned, its sensible effects are nearly the same, varying of course with the quantity taken, with the constitution of the taker, and with the frequency of its previous use. The essential and primary action of the drug is upon the nervous system.

When taken in a moderate dose, the usual results of this action are, that the mind is exhilarated, the ideas flow more quickly, and a pleasurable or comfortable condition of the whole system is experienced, which it is difficult to describe. It thus acts in a similar way to our wines and spirituous liquors, and it is chiefly as a substitute for these that it is used in China.

It possesses, however, a wonderful power of sustaining the strength, which is not found in alcoholic drinks, and of enabling men to undergo fatigue and continued exertion under which they would otherwise inevitably sink. Thus the Harkaras, who carry letters and run messages through the provinces of India, when provided only with a small piece of opium, a bag of rice, and a pot to draw water from the wells, perform almost incredible journeys. The Tartar couriers also, who travel for many days and nights continuously, make much use of it. With a few dates or a lump of coarse bread, they traverse the trackless desert, amidst privations and hardships which can only be supported under the influence of the drug—(Forbes). And hence travellers in the

[1] United States' Exploring Expedition, vol. ii. p. 299.

[2] Marsden's History of Sumatra, p. 238.

Ottoman dominions generally carry opium with them in the form of lozenges or cakes stamped with the Turkish legend, "Mash Allah," the gift of God—(GRIFFITH). Even the horses in the East are sustained by its influence. The Cutchee horseman shares his store of opium with his flagging steed, which thus makes an incredible stretch, though apparently wearied out before—(BURNES).

The Turkish Theriakis, or opium-eaters, generally begin with doses of from half a grain to two grains a-day, and gradually increase the quantity till it amounts to 120 grains, or sometimes more. The effect shows itself in one or two hours after it has been taken, and lasts for five or six. It produces a high degree of animation, which the Theriakis represent as the summit of happiness.

De Quincey took laudanum for the first time to dispel pain, and he thus describes the effect it had upon him: "But I took it, and in an hour, O heavens! what a revulsion! what an upheaving, from its lowest depths, of the inner spirit! what an apocalypse of the world within me! That my pains had vanished was now a trifle in my eyes. This *negative* effect was swallowed up in the immensity of those positive effects which had opened before me—in the abyss of divine enjoyment thus suddenly revealed. Here was a panacea—a *φάρμακον νηπενθές* for all human woes. Here was the secret of happiness, about which philosophers had disputed for so many ages, at once discovered! Happiness might now be bought for a penny, and carried in the waistcoat-pocket; portable ecstasies might be had corked up in a pint-bottle; and peace of mind could be sent down in gallons by the mail-coach."

Dr Madden describes more soberly his sensations when under the influence of the drug in one of the coffee-houses at Constantinople. "I commenced with one grain. In the course of an hour and a half it produced no perceptible effect. The coffee-house keeper was very anxious to give me an additional pill of two grains, but I was contented with half a one; and in another half-hour, feeling nothing of the expected reverie, I took half a grain more, making in all two grains in the course of two hours. After two hours and a half from the first dose, my spirits became sensibly excited; the pleasure of the sensation seemed to depend on a universal expansion

of mind and matter. My faculties appeared enlarged; everything I looked at seemed increased in volume; I had no longer the same pleasure when I closed my eyes which I had when they were open; it appeared to me as if it was only external objects which were acted on by the imagination, and magnified into images of pleasure; in short, it was 'the faint exquisite music of a dream' in a waking moment. I made my way home as fast as possible, dreading at every step that I should commit some extravagance. In walking, I was hardly sensible of my feet touching the ground; it seemed as if I slid along the street, impelled by some invisible agent, and that my blood was composed of some ethereal fluid, which rendered my body lighter than air. I got to bed the moment I reached home. The most extraordinary visions of delight filled my brain all night. In the morning I rose pale and dispirited; my head ached; my body was so debilitated that I was obliged to remain on the sofa all day, dearly paying for my first essay at opium-eating."[1]

These after-effects are the source of the misery of the opium-eater. The exciting influence of the drug is almost invariably followed by a corresponding depression. The susceptibility to external impressions and the muscular energy are both lessened. A desire for repose ensues, and a tendency to sleep. The mouth and throat also become dry; the thirst is increased; hunger diminishes; and the bowels usually become torpid.

When large doses are taken, all the above effects are hastened and heightened in proportion. The period of depression comes on sooner; the prostration of energy increases to actual stupor, with or without dreams; the pulse becomes feeble, the muscles exceedingly relaxed, and, if enough has been taken, death ensues.

Of course all these effects are modified by the constitution of the individual, by the length of time he has accustomed himself to take it, and by the circumstances in which he is placed. But upon all persons, and in all circumstances, its final effects, like those of ardent spirits taken in large and repeated doses, are equally melancholy and degrading. "A total attenuation of body," says Oppenheim, "a withered yellow countenance, a lame gait, a bending of the spine, fre-

[1] Madden's Travels in Turkey, vol. i. p. 25.

quently to such a degree as to assume a circular form, and glassy deep-sunken eyes, betray the opium-eater at the first glance. The digestive organs are in the highest degree disturbed; the sufferer eats scarcely anything, and has hardly one evacuation in a week. His mental and bodily powers are destroyed—he is impotent."

And then, "when the baneful habit has become confirmed, it is almost impossible to break it off. His torments, when deprived of the stimulant, are as dreadful as his bliss is complete when he has taken it. Night brings the torments of hell, day the bliss of paradise; and, after long indulgence, he becomes subject to nervous pains, to which opium itself brings no relief. He seldom attains the age of forty, if he have begun the practice early."

Dr Madden thus describes what he saw of its effects upon the confirmed Theriakis, as they are called, in the coffee-houses of Constantinople: "Their gestures were frightful; those who were completely under the influence of the opium talked incoherently, their features were flushed, their eyes had an unnatural brilliancy, and the general expression of their countenances was horribly wild. The effect is usually produced in two hours, and lasts four or five; the dose varies from three grains to a drachm. I saw one old man take four pills, of six grains each, in the course of two hours: I was told he had been using opium for five-and-twenty years. But this is a very rare example of an opium-eater passing thirty years of age, if he commence the practice early. The debility, both moral and physical, attendant on its excitement is terrible. The appetite is soon destroyed; every fibre in the body trembles; the nerves of the neck become affected, and the muscles get rigid: several of these I have seen in this place at various times, who had wry necks and contracted fingers; but still they cannot abandon the custom; they are miserable till the hour arrives for taking their daily dose; and when its delightful influence begins, they are all fire and animation. Some of them compose excellent verses, and others address the bystanders in the most eloquent discourses, imagining themselves to be emperors, and to have all the harems in the world at command."

The seductive influence of opium, and the almost irresistible and domineering power it acquires over the minds of its

votaries, are not less wonderful than the mental happiness it confers during the exciting stage of its action on the body. Of this power of seduction even over the less delicate and susceptible organisation of our North European races, and of the absolute slavery to which it can reduce even the strongest minds among us, we have two remarkable examples in the celebrated Coleridge, and in the author of the 'English Opium-Eater.' For many years Coleridge was a slave to opium, and the way in which he became addicted to it is thus described by himself, in a letter dated April 1814: "I was seduced into the accursed habit ignorantly. I had been almost bedridden for many months with swelling in my knees. In a medical journal I unhappily met with an account of a cure performed in a similar case, by rubbing in laudanum, at the same time taking a given dose internally. It acted like a charm—like a miracle. I recovered the use of my limbs, of my appetite, of my spirits; and this continued for near a fortnight. At length the unusual stimulus subsided, the complaint returned, the supposed remedy was recurred to—but I cannot go through the dreary history. Sufficient to say, that effects were produced which acted on me by terror and cowardice of pain and sudden death,"—and Coleridge became the slave of opium.

Subsequently, while living at the house of a friend in Bristol, he put himself in the hands of a medical man; and here the most melancholy part of his case exhibited itself. For, while he was pretending to be gradually lessening the dose under medical instructions, and while his friends were congratulating themselves that he was absolutely cured, by being brought down to twenty drops a-day, he was all the while buying laudanum secretly, and drinking it in large doses as before! How his moral sense must have been overborne, and by how powerful a fascination, before he could have stooped to a deception so degrading as this!

And how extreme his own misery and sense of impotence, when he could write of himself: "There is no hope. O God, how willingly would I place myself under Dr Fox in his establishment! for my case is a species of madness, only that it is a derangement, an utter *impotence of the volition*, and not of the intellectual faculties. You bid me rouse myself. Go bid a man, paralytic in both arms, to rub them briskly to-

gether, and that will cure him. 'Alas!' he would reply, 'that I cannot move my arms is my complaint and my misery.'"

And even greater misery he paints in another letter written in the same year (1814). "Conceive a poor miserable wretch, who for many years has been attempting to beat off pain by a constant recurrence to a vice that reproduces it. Conceive a spirit in hell employed in tracing out for others the road to that heaven from which his crimes exclude him! In short, conceive whatever is most wretched, helpless, and hopeless, and you will form as tolerable a notion of my state as it is possible for a good man to have."[1]

Coleridge lived twenty years after the above was written, and conquered the evil habit. But after what struggles and tortures, mental and bodily, who can tell? De Quincey also, after a seventeen years' use, and an eight years' abuse, of the powers of opium, shook off his slavery. He has left us a graphic and impressive sketch of the terrible trials and temptations he had to withstand in finally abandoning the drug. "On the 24th of June 1822," he says, "I began my experiment, having previously settled in my own mind that I would not flinch, but 'would stand up to the scratch' under any possible 'punishment.' About 170 or 180 drops had been my ordinary allowance for many months; occasionally I had run up as high as 300, and once nearly to 700: in repeated preludes to my final experiment, I had also gone as low as 100 drops, but had found it impossible to stand it beyond the fourth day, which, by the way, I have always found more difficult to get over than any of the preceding three. I went off under easy sail—130 drops a-day for three days; on the fourth I plunged at once to 80. The misery which I now suffered 'took the conceit out of me' at once; and for about a month I continued off and on about this mark: then I sunk to 60; and the next day to—none at all. This was the first day for nearly ten years that I had existed without opium. I persevered in my abstinence for ninety hours—*i.e.*, upwards of half a week. Then I took—ask me not how much. Say, ye severest, what would you have done? Then I abstained again; then took about 25 drops; then abstained,—and so on."[2]

[1] Cottle's Early Recollections, vol. ii. p. 185.

[2] Confessions of an English Opium-Eater, Appendix.

Under manifold pains, irritations, and distresses, some of which he has described, he manfully, and for months, persevered, and finally achieved his liberty. "I triumphed: but think not, reader, that therefore my sufferings were ended. Nor think of me as of one sitting in a *dejected* state. Think of me as of one, even when four months had passed, still agitated, writhing, throbbing, palpitating, shattered; and much in the situation of him who has been racked, as I collect the torments of that state from the affecting account of them by William Lithgow, the most innocent sufferer of the times of James I. Meantime, I derived no benefit from any medicine, except one prescribed for me by an Edinburgh surgeon of great eminence—ammoniated tincture of valerian."

What a lesson does the experience of these two men read to us!

Similar effects are described as resulting from the smoking of opium in China. It appears to be very much a matter of indifference, therefore, whether the drug be taken in the solid form of pills, in the liquid form of laudanum, or in the more subtle form of heated vapour. The smoke acts more immediately than the other forms of the drug, but its final effects are very much the same.

4°. Extent to which Opium is used.—It is impossible to arrive at anything like an approximate idea of the quantity of opium consumed by the different nations of the world. Meyen asserts that the quantity consumed by the Malays of the Indian Archipelago, in Cochin-China and Siam, as well as in India and Persia, is so immense that, if we could obtain an exact statement of it, the amount would be quite incredible. In India we know that the revenue derived from home-grown opium is enormous. In 1875 it amounted to more than 8½ millions sterling! Much of the drug represented by this figure is exported to China, but besides this, the quantity consumed in India itself must be immense. The Rajpoots, and other Hindoo tribes, present opium, at their visits and entertainments, with the same familiarity as the snuff-box is presented in Europe—(Forbes). And in some districts, as I have already mentioned, it is even administered to the horses. India exports much to the islands of the Indian Archipelago and other places. Malwa opium is grown by natives under

a system of excise. In Bengal, the Behar, and Benares, opium is a Government monopoly.

As to China, we know that, in the season 1837-38, it imported from India 3,000,000 lb., and the importation had increased to 11,500,000 lb. in 1856. To this importation must also be added the opium which China receives by land from the countries which border it towards the west, and that which is grown in the country itself—a large and increasing amount. In the province of Yünnan poppy-fields are seen everywhere, and every hut has its poppy-garden. The consumption of China at the present moment is certainly not less than 14,000,000 or 15,000,000 lb., having a market value of as many pounds sterling.

The consumption of the United Kingdom is of course trifling when compared with that of India or China; it is, however, greatly on the increase. Thus the quantity imported into Great Britain was—in

1839,	41,000 lb.	
1852,	114,000 ,,	
1876,	400,303 ,,	= £394,034.

The imports in 1876 were—from

Turkey,	315,624 lb.
Persia,	51,165 ,,
British India,	13,390 ,,
China,	5,660 ,,
Other countries,	14,464 ,,

Thus the imports have increased more than three times within the last fifteen years. This implies either the application of the drug to new purposes, or a greatly increased demand for the uses to which it was formerly applied.

Much uncertainty exists as to the extent to which the use of opium as a narcotic indulgence, in any of its forms, really prevails among our full-grown healthy adult population, either in town or country. According to De Quincey, opium-eaters were already numerous among us sixty years ago. But those he mentions were either persons of talent and eminence, whom the gnawings of indigestion drove to opium as a stiller of pain, or poverty-stricken operatives in Manchester and other large towns, who of a Saturday evening soothed their cares and stayed their hunger with a grain or two of opium. And although the opinion is hazarded from time to time that

the practice of opium-eating is extending among the body of the people, and individual cases occur now and then in which it is certain that the drug has been largely used,[1] yet statistical data are altogether wanting to support the idea that the consumption of opium as a narcotic indulgence is now, or is likely soon to become, a national vice among the inhabitants of any of the three kingdoms. Of course, there are in London and other large cities colonies of opium-eaters or opium-smokers.

Another form of the opium evil, however, has been shown, upon unquestionable evidence, extensively to prevail. In the large manufacturing towns of Lancashire it is a common thing for mothers who work in the factories to put out their children to nurse, and it is equally common for the nurses to dose the children with opium for the purpose of keeping them quiet or of setting them to sleep. It was stated by the Rev. Mr Clay, that in the town of Preston alone, in 1843, "upwards of sixteen hundred families were in the habit of using Godfrey's Cordial, or some other equally injurious compound;" and that in one of the burial clubs in that town, "sixty-four per cent of the members die under five years of age."[2] The obvious conclusion was, that the fatality among the children was connected with the use of the drug.

A writer in the 'Morning Chronicle' of the 4th of January 1850 thus describes the effects which this use of opium produces upon the health of the children: "The consequences of this system of drugging are suffusion of the brain, and an extensive train of mesenteric and glandular diseases. The child sinks into a low torpid state, wastes away to a skeleton, except the stomach, producing what is known as pot-belly. One woman said, 'The sleeping stuff made them that they were always dozing, and never cared for food. They pined away. Their heads got big, and they died.'"

[1] A child died, for example, from the effects of opium in September 1853, at Boxworth in Cambridgeshire, the mother, because it was unwell, having placed a piece of crude opium in its mouth to suck. To the announcement of this fact in the newspapers it was added, "that the mother and her family are all opium-eaters, and, though labouring people, spend 4s. a-week on the drug!" In my own frequent visits to the rural districts I have never heard of the use of opium as an indulgence in Scotland, and only in one country parish in the centre of England.

[2] First Report of the Commissioners of Inquiry into the State of Large Towns, 1844. Appendix, pp. 46, 48.

It cannot be denied, therefore, that in one melancholy form at least the evil effects of opium are to be seen amongst us. And it is curious that this should be the very form of drugging from which the poppy is said to have derived its name. The diffusion of knowledge among the mothers of the factory districts is one of the most likely ways to remove this evil.

5°. Chemical Constituents of Opium. — In regard to its chemical history, opium is probably the best known of all the complex vegetable extracts or inspissated juices used in medicine.

How very complicated a substance even the purest opium is, the general reader will infer from the formidable list of peculiar principles which have been found in it. Besides familiar substances, such as gum, mucilage, resin, fat, caoutchouc, volatile oil, &c., it contains morphine, narcotine, codeine, thebaine, papaverine, with ten other alkaloids, and meconic acid—sixteen peculiar organic compounds, which occur in greater or less quantity in nearly every sample of pure opium!

Of all these, the most characteristic is that now almost universally known under the name of morphine or morphia. Of this invaluable medicine the best qualities of opium contain as much as 10 per cent. It is a beautiful colourless crystalline substance, nearly insoluble in water, but having an exceedingly bitter unpleasant taste, and what are called by chemists alkaline properties. It is powerfully narcotic and poisonous, soothes nervous irritation, stills pain, and when taken in large doses, imparts a remarkable itchiness to the skin. It produces upon the system most of the effects of the natural opium. And there has arisen an actual morphia mania—an insatiable craving for this pure chemical compound—the chemical composition of which is fixed, and the physiological effects constant and certain, as a substitute for the crude and uncertain opium in the production of pleasurable excitement and gratification.

The full and peculiar effect of the natural drug is, however, due to the combined and simultaneous action of several out of the numerous substances it contains. Each of these modifies the effect which would be produced by any one of the others taken singly—as the attraction of each planet modifies the course which would be taken by every one of

the others, were it the only one which revolved round the sun. It is from the result of all these conjoined actions that the singular pleasure of the opium-consumer is derived.

The amount of opium taken modifies not only the extent of the effects of opium but also their character. A small dose excites the brain, but diminishes the secretions, except the perspiration, which is much increased. A moderate dose produces tranquillity and sleep, the flow of blood to the brain being lessened; a strong dose produces stupor and coma by impeding respiration.

Of the chief alkaloids of opium some are sleep-producing or soporific, while others are almost or quite destitute of this property. Again, some of them are more actively poisonous than others, while others are powerful allayers of pain. According to Rabuteau the chief opium-alkaloids may be grouped thus, the most active in each direction being placed first—

Sleep-producing.	Poisonous.	Pain-allaying.
Morphine,	Morphine,	Narceine,
Narceine,	Codeine,	Morphine,
Codeine.	Thebaine,	Thebaine,
	Papaverine,	Papaverine,
	Narceine,	Codeine.
	Narcotine.	

Thus thebaine is poisonous and pain-allaying, but not soporific. It is especially useful for injecting under the skin, for which morphine-salts are now so largely used. It must be confessed, however, that different experimenters do not perfectly agree as to the physiological actions of the several alkaloids of opium. This is to be explained in part by their experiments having often been made upon the lower animals instead of upon man.

6°. Average Composition of Opium.—The proportions in which the several active ingredients are present in the opium of commerce varies much in different samples of the drug. The country or locality in which the plant is grown, the variety of poppy which is cultivated, the state of ripeness when the poppy-head is cut, the peculiarities of the season during which the sap is collected, the way in which it is dried and afterwards prepared for market—all these circumstances influence the proportions of its constituents, and consequently modify the action of the mixed substance upon

the human system. The Smyrna opium is generally considered the best in the European market; but even in this the active ingredient morphine varies from 4 to 14 per cent. In a sample from Vermont, U.S., 16 per cent was found with 2 per cent of narcotine. The total amount of alkaloids in good Smyrna opium often rises to 24 per cent.

Morphine is the most valuable constituent of opium, and its percentage in the samples from different localities, determines very much their relative estimation in the market. Hence the best Indian opium is inferior to the Turkish. It never yields more than 5 per cent of morphine; but it is richer in the less esteemed ingredient narcotine. The opium of Persia is equally poor in morphine. Quite recently a valuable and powerful emetic has been made from morphine. This substance, called *apomorphine*, differs from morphine only in containing one proportion of water less.

These latter facts show that, though opium is chiefly collected and used in warm climates, yet mere warmth of climate, whatever may be its other effects on the white poppy, does not alone cause the juice of its ripening capsules to be rich in morphine. On the contrary, British and German grown opium has been found to contain more morphine than that of commerce, and opium collected in France has yielded as much as 16 to 28 per cent of this ingredient.

This large yield of morphine possesses in this part of the world more of a scientific than of an economical interest, since both the dearness of labour and the variableness of climate in the British Islands are opposed to the idea of a profitable cultivation of opium. It may possibly be otherwise in some parts of France, Germany, and, we may add, our Australian colonies. Recent experiments show that the poppy cultivated for its seed may be so treated as to yield a harvest of opium at an expense which need not exceed one-fourth of the market value of the drug obtained. And as the seed, which afterwards ripens uninjured, will pay all the ordinary cost of culture, it is believed by many that in the collection of opium there is the prospect of great future advantage to the agriculture of several countries where the experiment of opium poppy cultivation has been successfully inaugurated.

In this plant, as in tobacco, variety as well as locality has

an influence on the quantity of the active ingredients contained in its sap. Thus opium collected in Germany from the white poppy (variety *album*) yielded only 7 per cent of morphine, while other samples collected from the black poppy (variety *nigrum*) yielded 16½ per cent.

It is a singular circumstance in the physiological history of morphine and its compounds, that, though so poisonous to man, it can be swallowed with comparative impunity, and in large doses, by apes, dogs, cats, hares, birds, and other animals. A full dose of morphine for a grown man is one-eighth of a grain; and of acetate or hydrochlorate of morphine, one-fourth of a grain; but an ape has been known to swallow 500 grains of morphine in a single month. It passes off harmlessly in the urine, which, in the case of the above ape, sometimes contained as much as one per cent of morphine—(FLANDIN). And it has been found that the several alkaloids of opium have not the same poisonous effects upon the lower animals as upon man. Thebaine is the most deadly when given to cats and dogs; morphine to man.

It is a curious physiological fact, that even in man the active narcotic ingredients of opium often escape in the secretion of the kidneys. Morphine has been detected in the urine, and children have been poisoned by the milk of nurses who took much laudanum. This character the active constituents of opium possess in common with many other narcotic principles, such as those of the deadly nightshade, the henbane, the thorn-apple, the intoxicating fungus, and with many other substances used in medicine.

In India the opium is so much reduced in strength by admixtures of various kinds before it reaches the retailers in the bazaars, that it does not possess one-thirtieth of the intoxicating power of the natural drug—(HOOKER).[1] In Java, where it is a government monopoly, it is sold to Chinese dealers, who are bound to dilute it with tobacco and betel in a prescribed proportion, which varies with the quality of the opium, and to sell it thus reduced at a fixed price. Thus prepared for consumption, it is known by the name of *tandou*, and is extensively used. The opium-houses are only allowed to be open in the day-time, that accidents from quarrelling may be as much as possible prevented.

[1] Himalayan Journals, vol. i. p. 86.

7°. Influence of Race and Constitution.—This precaution is the more necessary in Java, because of the peculiarly exciting influence which opium exercises over the Javanese, the Malays, and the negro races.

Although both Coleridge and De Quincey have given such glowing descriptions of the action of opium in their individual cases, yet the British opium-eater in general is by no means subject to the extraordinary excitement either of body or of mind which these writers describe. The common effect, according to Dr Christison, "is merely to remove torpor and sluggishness, and to make the opium-consumer, in the eyes of his friends, an active and conversable man."[1]

But, as we have seen, the general effects of the drug in Turkey and Persia, as related by travellers, are very different. And they are still more exciting in the Indian Archipelago, and among some of the African races.

"The Javanese," says Lord Macartney, "under an extraordinary dose of opium, became frantic as well as desperate. They acquire an artificial courage; and, when suffering from misfortune and disappointment, they not only stab the objects of their hate, but sally forth to attack in like manner every person they meet, till self-preservation renders it necessary to destroy them." They shout, as they run, *Amok, amok!* which means, "kill, kill;" and hence the phrase, *running amuck.* Captain Beeckman was told of a Javanese who ran amuck in the streets of Batavia, and had killed several people, when he was met by a soldier, who ran him through with his pike. But such was the desperation of the infuriated man, that he pressed himself forward on the pike, until he got near enough to stab his adversary with a dagger, when both expired together.

On the Malays the effects of opium are described as being nearly the same both in kind and in degree. In reading of them, one is reminded of the excitement which formerly prevailed in a less fatal form at Donnybrook and other Irish fairs, when an unusual dose of poteen had been administered to the *boys.*

The influence of race, as it affects the physiological action either of substances introduced into the stomach, or of ideas presented to the mind, is the same in kind as the influence of

[1] Treatise on Poisons, p. 721.

individual constitution. It is only greater in degree, and startles us sometimes because of the extent to which it appears exaggerated. The influence of constitution is recognised and considered in every dose of medicine we take or administer, and in the way in which good or evil tidings are communicated to our friends. We more rarely allow for differences of race in dealing with foreign nations, or in criticising their behaviour and actions under given circumstances.

In the Malays and Javanese we have the excitable temperament, accompanied by the unrestrained outward forms of expression which are characteristic of Eastern nations. What affects us Anglo-Saxons lightly or slowly, touches them instantly, and penetrates deep. The emotions which, when awakened, we are accustomed to restrain and hide, they openly and vividly display, and by indulgence heighten often to an overpowering degree. The negro tribes partake of a similar organisation. Their susceptibility affects all their relations both to living and dead things. Opium operates upon different individuals among them in different ways, as it does upon the different individuals of European races; but upon all of them it produces those more marked and striking effects which, among ourselves, we only see in rare instances, and in persons of uncommonly nervous temperament.

A singular illustration of the effect of mixed substances upon the human constitution, when in a state of disease, is presented in the use of a mixture of opium with corrosive sublimate by the confirmed opium-eaters of the East. The drug, in its usual form, gradually loses its effect upon the habitual consumer, so that the dose must be increased from time to time, if the influence of the drug is to be maintained. But at length even this resource fails the inveterate opium-eaters of Constantinople, and no increase of dose will procure for them the desired enjoyment, or even relieve them from bodily pain. In this emergency, they have recourse to the poisonous corrosive sublimate. Mixing at first a minute quantity of this substance with their daily dose of opium, they increase it by degrees, till they reach the limit of ten grains a-day, beyond which it is usually unsafe to pass. This mixture acts upon their long-tortured frames, when neither of the ingredients, taken alone, will either soothe or exhilarate. But the use of the new medicine only protracts a little longer the artificial

enjoyment, which has become a necessary of life, finally bringing to a more miserable termination the career of the debilitated and distorted Theriaki.

8°. OPIUM COMPARED WITH WINE.—I have said that in moderate doses opium acts in a similar way to our wines and spirituous liquors, and that it is as a substitute for these that the Chinese use it. By this I do not mean that its physiological effects are precisely the same, although the main purpose for which both are used by many—that of dispelling care—may be the same. On the contrary, there are many points of difference in the effects which alcoholic drinks and opium respectively produce.

The English Opium-Eater thus enumerates some of the points by which, according to his experience, their several actions are distinguished: "Wine robs a man of his self-possession; opium greatly invigorates it. Wine unsettles and clouds the judgment, and gives a preternatural brightness and a vivid exaltation to the contempts and the admirations, the loves and the hatreds, of the drinker: opium, on the contrary, communicates serenity and equipoise to all the faculties, active or passive; and with respect to the temper and moral feelings in general, it gives simply that sort of vital warmth which is approved by the judgment, and which would probably always accompany a bodily constitution of primeval or antediluvian health. . . . To sum up all in one word, a man who is inebriated, or tending to inebriation, is, and feels that he is, in a condition which calls up into supremacy the merely human—too often the brutal—part of his nature; but the opium-eater (I speak of him who is not suffering from any disease, or other remote effects of opium) feels that the diviner part of his nature is paramount; that is, the moral affections are in a state of cloudless serenity; and over all is the great light of the majestic intellect."

This language of the Opium-Eater must be read with that amount of allowance which we naturally concede to poetical writers, who aim at effect in the language they select, and are not afraid of the startling and uncommon.

9°. IS OPIUM NECESSARILY DELETERIOUS?—We have been in the habit, in this country, of regarding the use of opium in the way of indulgence as an unmitigated evil. And although to accede to the highly-coloured eulogium of Mr De Quincey

would be to rush to the opposite extreme, yet it may perhaps be conceded that our attention has been generally too much directed to the most dismal features of the practice, and that we may have judged too hastily as to its more general effects. Thus Dr Burnes, long resident in Cutch and at the Court of Scinde, says, that "in general the natives do not suffer much from the use of opium:" and that it "does not seem to destroy the powers of the body, nor to enervate the mind, to the degree that might be imagined." And as to the Chinese, Dr Macpherson observes, that "although the habit of smoking opium is universal among rich and poor, yet they are a powerful, muscular, and athletic people, and the lower orders more intelligent, and far superior in mental acquirements, to those of corresponding rank in our own country."

Among those also who have seen much of the use of opium in Eastern countries, there are some who, so far from pronouncing the practice to be an unmitigated evil, actually prefer its general use to that of alcoholic drinks. Thus Dr Eatwell wrote—

"The question to be determined is not what are the effects of opium used in excess, but what are its effects on the moral and physical constitution of the mass of individuals who use it habitually, and in *moderation*, either as a stimulant to sustain the frame under fatigue, or as a restorative and sedative after labour, bodily or mental? Having passed three years in China, I can affirm thus far, that the effects of the abuse of the drug do not come very frequently under observation, and that when cases do occur, the habit is frequently found to have been induced by the presence of some painful chronic disease, to escape from the sufferings of which the patient has fled to this resource. That this is not always the case, however, I am perfectly ready to admit; and there are doubtless many who indulge in the habit to a pernicious extent, led by the same morbid influences which induce men to become drunkards in even the most civilised countries; but these cases do not, at all events, come before the public eye. As regards the effects of the habitual use of the drug on the *mass* of the people, I must affirm that no injurious results are visible. The people generally are a muscular and well-formed race, the labouring portion being capable of great and prolonged exertion under a fierce sun, in an unhealthy climate.

Their disposition is cheerful and peaceable, and quarrels and brawls are rarely heard even amongst the lower orders; whilst in general intelligence they rank deservedly high amongst orientals.

"I conclude, therefore, with observing, that the proofs are still wanting to show that the moderate use of opium produces more pernicious effects upon the constitution than the moderate use of spirituous liquors; whilst at the same time it is certain that the consequences of the abuse of the former are less appalling in their effects upon the victim, and less disastrous to society at large, than the consequences of the abuse of the latter."[1]

That the effects of opium-eating and opium-smoking in China are not so melancholy as we have been accustomed to suppose, and that, on the whole, they are not worse than those which are produced among ourselves by fermented liquors—this is the substance of Dr Eatwell's testimony; and so far it is both interesting and satisfactory. But his language is not laudatory like that of De Quincey. He palliates the vicious indulgence, but says nothing which should recommend the practice to his readers. The medical missionaries to China inform us that confirmed opium-consumers use daily from thirty to two hundred grains of the pure extract, which is equal to twice as much of the crude opium.[2] But were such cases very numerous, they ought to come more frequently under the public eye than, from the testimony of Dr Eatwell, appears to be the case.

10°. Practical Conclusions.—The true state of the question in its practical bearings upon ourselves may be summed up as follows:—

First, It is certain that opium, like spirituous liquors, produces most melancholy body-and-soul-destroying effects upon those who give themselves up to its use as a narcotic indulgence. If day brings them the bliss of heaven, night brings with it the torments of hell.

Secondly, It is certain also that some can continue for years to use it in small doses as a narcotic indulgence, without becoming slaves to it, or without appearing to be sensibly affected by it in their general health.

1 Pharmaceutical Journal, vol. xi. p. 364.

2 Ten grains cost 22 cash, about one penny.

Thirdly, But it is of all indulgences the most wonderfully seductive, and is therefore a most dangerous substance to become familiar with. The infatuation sometimes reaches such a point that the certainty of death, and of all the fearful infirmities which in this case precede death, have no influence on the victim. He coldly answers those who warn him of his danger that the opium happiness is beyond compare—(POUQUEVILLE).

Fourthly, That to give up the indulgence produces tortures of mind and body which make cowards and recreants of the most resolute. To this fact, the testimony of Coleridge and De Quincey has been already quoted.

Am I then—is the practical question each of my readers will put to himself—am *I* possessed of moral and physical courage, such as will enable *me* to resist the fascinations of this insidious drug, to give it to, or to withhold it from, *myself*, as may be most for my good? Do those around me, and who may be influenced by my example, possess equal self-control? The wisest, I believe, will hesitate to answer these questions in the affirmative, and, for themselves and those they love, will most anxiously shun the great risk.

VI. SUBSTITUTES FOR OPIUM.—Substitutes for opium have been sought for and used in different countries.

1°. *Bull-hoof.*—In Jamaica, the *Muracuja ocellata*, or bull-hoof, has been called Dutchman's laudanum, because certain parts of the plant are supposed to possess the same virtues as the poppy. The flowers are principally employed, and when infused or mixed in the state of powder with wine or spirits, they are regarded as a safe and effectual narcotic—(BROWN).

2°. *The Lettuce.*—In Europe, the different species of the lettuce (*Lactuca*) are capable, to a certain extent, of supplying the place of the poppy. The juice of these plants, when collected and dried, has considerable resemblance to opium.

If the stem of the common lettuce, when it is coming into flower, be wounded with a knife, a milky juice exudes. In the open air this juice gradually assumes a brown colour, and dries into a friable mass. The smell of this dried juice is strongly narcotic, recalling that of opium. It has a slightly pungent taste, but, like opium, leaves a permanent bitter in

the mouth. It acts upon the brain after the manner of opium, and induces sleep.

To this crude extract the name of *Lactucarium* has been given by its discoverer, Professor Duncan of Edinburgh, who was followed by many physicians in its use as a sedative. Like opium, it dissolves in water to the extent of about one-half, and in this soluble portion the narcotic virtue resides. The principal active ingredient is supposed to be a peculiar substance named *lactucin*, of which the crude extract contains about one-fourth of its weight. It contains other active ingredients, however—the chemical nature and physiological influence of which have not as yet been rigorously investigated.

The lactucarium is one of those narcotics in which many of us unconsciously indulge. The eater of green lettuce as a salad takes a portion of it in the juice of the leaves he swallows; and many of my readers, after this is pointed out to them, will discover that their heads are not unaffected after indulging copiously in a lettuce salad. Eaten at night, the lettuce causes sleep; eaten during the day, it soothes and calms and allays the tendency to nervous irritability. Galen found no better remedy for the wakefulness of his old age. And yet the lover of lettuce would probably take it very much amiss if he were told that he ate his green leaves, partly at least, for the same reason as the Turk or Chinaman takes his whiff from the tiny opium-pipe—that, in short, he was little better than an opium-eater, and his purveyor than the opium-smugglers on the coast of China.

3°. *Syrian Rue.*—The seeds of the *Peganum Harmala*, the Syrian or Steppe rue, a plant abundant in the Crimea, are used by the Turks as a spice, and as a red dye. But they are also eaten as a narcotic indulgence, in the place of opium and hemp. I do not know to what extent this practice now prevails; but, according to Belonius, the Turkish emperor Solyman kept himself intoxicated by the use of the seeds of Syrian rue.

The active virtues of this seed appear to reside in its husk, which contains about 4 per cent of two alkaloids called respectively Harmine and Harmaline. To these substances the physiological action of Syrian rue may probably be attributed.

CHAPTER XVIII.

THE NARCOTICS WE INDULGE IN.

INDIAN HEMP.

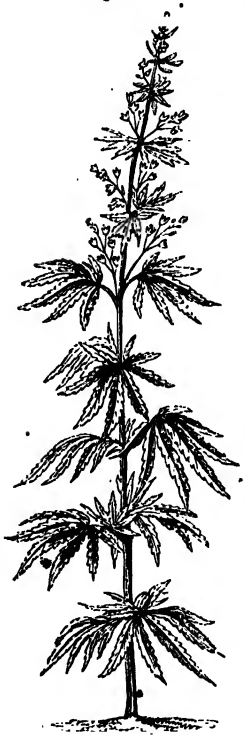
The common European the same as the Indian hemp.—Its narcotic resin more abundant in warm climates.—Mode of collecting the resin.—The Churrus or Kirs, Gunjah, Bang, and alcoholic extract.—Forms in which the hemp is used.—The Haschisch of Turkey.—Antiquity and extent of its use.—The Nepenthes of Homer, an Egyptian drug.—The tombeki of India.—Origin of the word "assassin."—Use of hemp in Africa and America.—Effects of hemp on the system.—Sometimes produces catalepsy.—Experience of M. Moreau.—Excitability produced by it.—Errors of perception.—Its effects vary with the individual and with the race; influence on orientals greater, on Europeans less.—Experience of M. de Saulcy.—Chemistry of the hemp plant; its volatile oil.—The natural resin and resinous extract probably contain several substances.—Hemp compared with opium; differences in their comparative effects.—Extent to which hemp is used.—Hemp in Afghanistan.

VII. Indian Hemp.—Little is popularly and practically known in northern Europe of the use of hemp as a narcotic indulgence; yet in the East it is as familiar to the sensual voluptuary as the opium treated of in the preceding chapter.

Our common European hemp (*Cannabis sativa*), fig. 59, so extensively cultivated for its fibre, is the same plant with the Indian hemp, which from the remotest times has been celebrated among Eastern nations for its narcotic virtues. The plant came to Europe from Persia, and is supposed by many to be a native of India; but, like tobacco and the potato, it has a wonderful power of adapting itself to differences in soil and climate. Hence it is now cultivated, not merely on the

plains of Persia, India, and Arabia, but in Africa, from its northern to its southern extremities; in America, all over its north-eastern states and provinces, and on the flats of Brazil; and in Europe, in almost every kingdom and country. In northern Russia it is an important article of culture, even as far north as Archangel, and from that region our manufacturers have been accustomed to receive large supplies of its valuble fibre.

Fig. 59.



Cannabis sativa—The cultivated Hemp.
Scale, half inch to a foot.

In the sap of this plant—probably in all countries—there exists a peculiar resinous substance, in which the esteemed narcotic virtue resides. In northern climates, the proportion of this resin in the several parts of the plant is so small as to have escaped general observation. The whole plant, indeed, has a peculiar smell, even when grown in Europe, which, though not unpleasant to every one, often gives headache and giddiness to persons who remain long in a hemp-field. This probably arises from an escape into the air of a small quantity of a volatile narcotic principle.

But in the warmer regions of the East, the resinous substance is so abundant as to exude naturally, and in sensible quantity, from the flowers, from the leaves, and from the young stems of the hemp plant. We have already seen that climate modifies considerably the proportions of the active ingredients contained in the dried leaf of tobacco, and in the dried juice of the poppy. The hemp plant exhibits a still more striking illustration of the influence of climate upon the chemical changes which take place in the interior of living vegetables. It grows well, and produces abundance of excellent fibre in the north, but no sensible proportion of narcotic resin. It grows still better, and more

magnificently, in tropical regions; but there its fibre is unheeded, while for the resin it spontaneously yields it is prized and cultivated.

1°. Mode of Collecting the Resin and Plant.—In India the resinous exudation of the hemp plant is collected in various ways. In Nepaul it is gathered by the hand in the same way as opium. This variety is very pure, and much prized. It is called *momeea*, or waxen *churrus*. It remains soft, even after continued drying; has a fragrant narcotic odour, which becomes strong and aromatic on heating. Its taste is slightly hot, bitterish, and acrid, yet balsamic. In Central India, men covered with leather aprons run backwards and forwards through the hemp-fields, beating the plants violently. By this means the resin is detached and adheres to the leather. This is scraped off, and is the ordinary churrus of Cabul. It does not bring so high a price as the momeea. In other places the leather aprons are dispensed with, and the resin is collected on the naked skins of the coolies. In Persia, it is collected by pressing the resinous plant on coarse cloths, and afterwards scraping the resin from these, and melting it in a little warm water. The churrus, or "kirs," of Herat is considered one of the best and most powerful varieties of the drug.

The plant itself is often collected and dried for the sake of the resin it contains. The whole plant gathered when in flower, and dried without the removal of the resin, is called *gunjah*. In this form it is sold in the markets of Calcutta in bundles about three inches in diameter, and containing each twenty-four plants. The larger leaves and seed-capsules separated from the stalks are called *bang*, *subjee*, or *sidhee*. This form is less esteemed than the gunjah.[1] The tops and tender parts of the plant, the flowers, and even the pistils of the flowers, are separated, and when dried alone are very powerful, and much esteemed. The seeds, I believe, are never used as a narcotic indulgence. In some medical works they are spoken of as cramp-stilling and pain-removing; but if they really possess these virtues, it must be in a very inferior degree; and they probably reside in the husk,[2] and not in the body of the seed itself.

[1] Pharmaceutical Journal, vol. i. p. 490.

[2] As is the case with the Syrian rue, *Peganum Harmala*, described at the close of the preceding chapter.

When boiled in alcohol, the gunjah yields as much as one-fifth of its weight of resinous extract, and hence this method of preparing the drug in a pure state has been recommended as the most efficient and economical. I am not aware, however, that it is anywhere adopted in the East.

2°. FORMS IN WHICH HEMP IS USED.—Among the ancient Saracens and the modern Arabs, in some parts of Turkey, and generally throughout Syria, the preparations of hemp in common use were, and are still, known by the names of *haschisch*, *hashash*, or *husheesh*. The most common form of haschisch, and that which is the basis of all others, is prepared by boiling the leaves and flowers of the hemp with water to which a certain quantity of fresh butter has been added, evaporating the decoction to the thickness of a syrup, and then straining it through cloth. The butter thus becomes charged with the active resinous principle of the plant, and acquires a greenish colour. This preparation retains its properties for many years, only becoming a little rancid. Its taste, however, is very disagreeable, and hence it is seldom taken alone, but is mixed with confections and aromatics—camphor, cloves, nutmegs, mace, and not unfrequently ambergris and musk—so as to form a sort of electuary. The confection used among the Moors is called *el mogen*, and is sold at an enormous price. *Dawamese* is the name given by the Arabs to that which they most commonly use. This is frequently mingled, however, with other substances of reputed aphrodisiac virtues, to enable it to administer more effectually to the sensual gratifications, which are the grand object of life among many of the orientals.

The Turks give the names of *hadschy malach* and *madjoun* to the compositions they use for purposes of excitement. According to Dr Madden, the madjoun of Constantinople is composed of the pistils of the flowers of the hemp plant ground to powder, and mixed in honey with powdered cloves, nutmegs, and saffron.

Thus the Indian hemp and its products are used in one or other of four different forms:—

First, The whole plant dried and known by the name of gunjah; or the larger leaves and capsules dried and known as bang, subjee, or sidhee; or the tops and tender parts of the plants collected after they have been in flower, and which in some places are called haschisch; or the dried flowers,

called in Morocco *kief*, a pipe of which, scarcely the size of an English pipe, is sufficient to intoxicate; or the dried pistils of the flower as they enter into the composition of the madjoun of the Turks. These several parts of the dried plant, when newly gathered, have a rapid and energetic action. Their efficacy diminishes, however, by keeping.

Secondly, The resin which naturally exudes from the leaves and flowers, and is, when collected by the hand, called momeea; or the same beaten off with sticks, and sold by the name of churrus.

Thirdly, The extract obtained by the use of butter, which, when mixed with spices, forms the dawamese of the Arabs, and is the foundation of the haschisch of many Eastern countries and districts.

Fourthly, The extract obtained by means of alcohol from the gunjah. This is said to be very active, but I am not aware of its being in use in the East.

The dried plant is smoked and sometimes chewed. Five or ten grains reduced to powder are smoked from a common pipe along with ordinary tobacco, or from a water pipe (*narghilé*), with a variety of tobacco called tombeki.[1] The resin and resinous extract are generally swallowed in the form of pills or boluses.

3°. Antiquity and Extent of its Use.—In one or other of the forms above mentioned the hemp plant appears to have been used from very remote times. The ancient Scythians are said by Herodotus to have excited themselves by "inhaling its vapour." Homer makes Helen administer to Telemachus, in the house of Menelaus, a potion prepared from the nepenthes, which made him forget his sorrows. This plant had been given to her by a woman of Egyptian Thebes; and Diodorus Siculus states that the Egyptians laid much stress on this circumstance, arguing that Homer must have lived among them, since the women of Thebes were actually noted for possessing a secret by which they could dissipate anger or melancholy. This secret is supposed to

[1] The tombeki is said by some writers to be a peculiarly strong variety of tobacco, while others consider it to be the leaf of a species of Lobelia. It is smoked in a narghilé, and is exceedingly narcotic; so much so that it is usually steeped in water for a few hours, to weaken it before it is used, and the pipe is charged with it while it is still wet.

have been a knowledge of the qualities of hemp. Under the name of *beng* it is also mentioned in the 'Arabian Nights,' translated by Lane, as the narcotic used by Haroun al Raschid and other heroes of the tales.

It is curious how common and familiar words sometimes connect themselves with things and customs of which we know absolutely nothing. The word *assassin*—a foreign importation now long naturalised among us—is of this kind. M. Sylvester de Sacy, the well-known orientalist, says that this word was derived from the Arabic name of hemp. It was originally used in Syria to designate the followers of "the old man of the mountain," who were called *Haschischins*, because among them the haschisch was in frequent use, especially during the performance of certain of their mysterious rites. Others say that, during the wars of the Crusaders, certain of the Saracen army, intoxicated with the drug, were in the habit of rushing into the camps of the Christians and committing great havoc, being themselves totally regardless of death; that these men were known by the name of hashasheens, and that thence came our word "assassin." The oriental term was probably in use long before the time of the Crusades, though the English form and use of the word may have been introduced into Europe at that period.

Nor is the use of hemp less extended than it is ancient. In the plains of India it is consumed in every form, and on the slopes of the Himalayas it is cultivated for smoking, as high up as the valleys of Sikkim. In Persia, in the east of Europe, and in Mohammedan countries, it is in extensive use. In Northern Africa it is largely employed by the Moors. In central and tropical Africa it is almost everywhere known as a powerful medicine and a desired indulgence. In Southern Africa the Hottentots use it under the name of *dacha*, for purposes of intoxication; and when some Bushmen were in London, they smoked the dried plant in short pipes made of the tusks or teeth of animals. And what is more astonishing, when we consider the broad seas which intervene, even the native Indians of Brazil know its value, and delight in its use; so that over the hotter parts of the globe generally, wherever the plant produces in abundance its peculiar narcotic principle, its virtues may

be said to be known, and more or less extensively made use of.[1]

4°. Effects of Hemp on the System.—This wide use of the plant implies that the effects of hemp upon the system are generally very agreeable. In India it is spoken of as the increaser of pleasure, the exciter of desire, the cementer of friendship, the laughter-mover, and the causer of the reeling gait—all epithets indicative of its peculiar effects. Linnæus describes its power as "narcotica, phantastica, dementens, anodyna et repellens;" while in the words of Endlicher, "Emollitum exhilarat animum, impotentibus desideriis tristem, stultam lætitiam provocat, et jucundissima somniorum conciliat phantasmata." Livingstone describes it as "producing a kind of frenzy; and Sebituane's soldiers, on coming in sight of their enemies, sat down and smoked it in order that they might make an effective onslaught. It produces different effects on different persons. Some view everything as if looking through the wide end of a telescope, and others, in passing over a straw, lift up their feet as if about to cross the trunk of a tree."[2]

a. The effects of the *churrus* or natural resin have been carefully studied in India by Dr O'Shaughnessy. He states, that when taken in moderation it produces increase of appetite and great mental cheerfulness, while in excess it causes a peculiar kind of delirium and catalepsy. This last effect is very remarkable, and we quote his description of the results of one of his experiments with what is considered a large dose for an Indian patient:—

"At 2 P.M. a grain of the resin of hemp was given to a rheumatic patient; at 4 P.M. he was very talkative, sang, called loudly for an extra supply of food, and declared himself in perfect health. At 6 P.M. he was asleep. At 8 P.M. he was found insensible, but breathing with perfect regularity. His pulse and skin were natural, and the pupils freely contracted on the approach of light. Happening by chance to lift up the patient's arm, the professional reader will judge of my astonishment when I found it remained in the posture in which I placed it. It required but a very brief examination of the limbs to find that by the influence of

[1] See Map of the Distribution of the Narcotics, p. 265.

[2] Missionary Travels, p. 540.

this narcotic the patient had been thrown into the strangest and most extraordinary of all nervous conditions, which so few have seen, and the existence of which so many still discredit—the genuine catalepsy of the nosologist. We raised him to a sitting posture, and placed his arms and limbs in every imaginable attitude. A waxen figure could not be more pliant or more stationary in each position, no matter how contrary to the natural influence of gravity on the part! To all impressions he was meanwhile almost insensible."

This extraordinary influence he subsequently found to be exercised by the hemp extract upon other animals as well as upon man. After a time it passes off entirely, leaving the patient altogether uninjured.

In this effect of the hemp in India we see a counterpart of many of the wonderful feats performed by the fakeers and other religious devotees of that country. It indicates probably the true means also by which they are enabled to produce them.

How much power a little knowledge gives to the dishonest and designing of every country, over the ignorant and unsuspecting masses!

b. Again, the effects of the *haschisch* of the Arabians, which probably differ little from those of hemp taken in any of its forms, have been described to us from his own personal experience by a French physician, M. Moreau. When taken in small doses, its effect, he says, is simply to produce a moderate exhilaration of spirits, or at most a tendency to unseasonable laughter. Taken in doses sufficient to induce the *fantasia*, as its more remarkable effects are called in the Levant, its first influence is the same as when taken in a small dose; but this is followed by an intense feeling of happiness, which attends all the operations of the mind. The sun shines upon every thought that passes through the brain, and every movement of the body is a source of enjoyment. M. Moreau made many experiments with it upon his own person—appears indeed to have fallen into the habit of using it even after his return to France—and he describes and reasons upon its effects as follow:—

"It is really *happiness* which is produced by the haschisch; and by this I mean an enjoyment entirely moral, and by no

means sensual, as might be supposed. This is a very curious circumstance, and some remarkable inferences might be drawn from it. . . . For the haschisch-eater is happy, not like the gourmand, or the famished man when satisfying his appetite, or the voluptuary in the gratification of his amative desires—but like him who hears tidings which fill him with joy, or like the miser counting his treasures, the gambler who is successful at play, or the ambitious man who is intoxicated with success."

This glowing description of the effects of the haschisch, though given by one who had often used it, is on that very account, like the pictures of the opium-eater, open to suspicion. We feel as if it were intended as a kind of excuse or justification of the indulgence on the part of the writer.

When first it begins to act, the peculiar effects of the haschisch may be considerably diminished, or altogether checked, by a firm exertion of the will, "just as we master the passion of anger by a strong voluntary effort." By degrees, however, the power of controlling at will and directing the thoughts diminishes, till finally all power of fixing the attention is lost, and the mind becomes the sport of every idea which either arises within itself, or is forced upon it from without.

"We become the sport of impressions of every kind. The course of our ideas may be broken by the slightest cause. We are turned, so to speak, by every wind. By a word or a gesture, our thoughts may be successively directed to a multitude of different subjects with a rapidity and lucidity which are truly marvellous. The mind becomes possessed with a feeling of pride, corresponding to the exaltation of its faculties, which it is conscious have increased in energy and power. The slightest impulse carries it along. Hence those who make use of the haschisch in the East, when they wish to give themselves up to the intoxication of the *fantasia*, withdraw themselves carefully from everything which could give to their delirium a tendency to melancholy, or excite anything but feelings of pleasurable enjoyment. They profit by all the means which the dissolute manners of the East place at their disposal. It is in the midst of the harem, surrounded by their women, under the charm of music and of lascivious dances performed by the almeh, that they enjoy

the intoxicating *dawamese;* and, with the aid of superstition, they find themselves almost transported to the scene of the numberless marvels which the Prophet has collected in his paradise."

The errors of perception, in regard to time and place, to which the patient is liable during the period of fantasia, are remarkable. Minutes seem hours, and hours are prolonged into years, till at last all idea of time seems obliterated, and the past and the present are confounded together. Every notion, in this curious condition, seems to partake of a certain degree of exaggeration. One evening M. Moreau was traversing the passage of the opera when under the influence of a moderate dose of haschisch. He had made but a few steps when it seemed to him as if he had been there for two or three hours; and as he advanced the passage seemed interminable, its extremity receding as he pressed forward.

The effect produced by hemp in its different forms varies, like that of opium, both in kind and in degree, with the race of men who use it, and with the individual to whom it is administered. Upon orientals, its general effect is of an agreeable and cheerful character, exciting them to dance, laugh, and sing, and to commit various extravagances—acting as an aphrodisiac, and increasing the appetite for food. Some, however, it renders excitable and quarrelsome, and disposes to acts of violence. It is from the extravagant behaviour of individuals of this latter temperament that the use and meaning of our word assassin have most probably arisen. It is from such effects of this substance also that we obtain a solution of the extravagances and barbarous cruelties which we read of as practised occasionally by Eastern despots.

Yet, even among orientals, according to Dr Moreau, there are some on whom the drug produces no effect whatever—upon whom, at least, doses are powerless which are usually followed by well-marked phenomena. As is the case with opium, long use also makes larger doses necessary. To some even a drachm of the churrus becomes a moderate dose, though sufficient to operate upon twenty ordinary men.

Upon Europeans generally, at least in Europe, its effects have been found to be considerably less in degree than upon orientals. "In India, Dr O'Shaughnessy had seen marked effects from half a grain of the extract, or even less, and had

been accustomed to consider one grain and a half a large dose; in England he had given ten or twelve or more grains to produce the desired effect."[1] In kind, also, its effects upon Europeans differ somewhat from those produced upon Asiatics. It has never been known, for example, to produce that remarkable cataleptic state, described in a previous page as having been observed in India even from a comparatively small dose of the hemp extract; nor, so far as I am aware, has it ever obtained a footing in any part of Europe as a narcotic indulgence.

It requires, indeed, a long and gradual training to its use before its boasted effects can be fully experienced, and this, fortunately, is not attempted yet in Europe. While in Jerusalem, M. de Saulcy, with the view of passing pleasantly a tedious evening, indulged himself in a dose of haschisch, which, upon his uninitiated constitution, produced only unpleasant results. He thus speaks of it—

"The experiment to which we had recourse for passing our time, turned out so utterly disagreeable that I may safely say not one of us will ever be tempted to try it again. The *haschisch* is an abominable poison, which the dregs of the population alone drink and smoke in the East, and which we were silly enough to take in too large a dose on the eve of New-Year's Day. We fancied we were going to have an evening of enjoyment, but we nearly died through our imprudence. As I had taken a larger dose of this pernicious drug than my companions, I remained almost insensible for more than twenty-four hours; after which I found myself completely broken down, with nervous spasms, and incoherent dreams, which seemed to have endured a hundred years at least."[2]

5°. Chemical Constituents of the Indian Hemp.—The volatile oil and the resin of hemp are the only two substances which chemists have yet extracted from this remarkable plant.

a. The volatile oil.—When distilled with water, the dried leaves and flowers, like those of the hop, yield a volatile oil, which is lighter than water. It is a hydrocarbon ($C_9 H_{10}$), and goes under the name of Cannabene. It is associated with small quantities of a white crystalline substance. Cannabene

[1] Pereira—Materia Medica, p. 1242.

[2] Journey round the Dead Sea, by F. de Saulcy, vol. i. p. 140.

has a powerful intoxicating action, but is less active than the natural resin.

b. The natural resin.—The whole hemp plant is impregnated, especially in warm climates, with a resinous substance, in which its most active virtues reside. When collected as it naturally exudes, this resin forms the churrus of India. It is extracted when the leaves are boiled with butter to form the basis of the haschisch, or when the dried plant is treated with alcohol to obtain the hemp extract. It is soft, dissolves readily both in alcohol and ether, and is separated from these liquids in the form of a white powder when the solutions are mixed with water. It has a warm, bitterish, acrid, somewhat balsamic taste, and a peculiar odour, especially when heated. The exact composition of hemp-resin has not been ascertained. It has been stated to contain nicotine, the active principle of tobacco, but it is probably a mixture of several substances possessed of different properties and relations to animal life. The remarkably complex composition of opium justifies such an opinion. And the analogy of the same substance makes it probable that the produce of the plant will differ in different localities and countries—so that the churrus of India, and the haschisch of Syria, may produce very different effects on the same constitution.

6°. Hemp compared with Opium.—The extract of hemp differs considerably from opium, not only in its sensible properties, but in its effects upon the system. It does not lessen but rather excites the appetite. It does not occasion nausea, dryness of the tongue, constipation, or lessening of the secretions, and is not usually followed by that melancholy state of depression to which the opium-eater is subject. It differs also in causing dilatation of the pupil, and sometimes catalepsy, in stilling pain less than opium does, in less constantly producing sleep, in the peculiar inebriating quality it possesses, in the phantasmata it awakens, and in its aphrodisiac effects. It operates likewise in a smaller dose, and does not produce that apathy to external impressions by which opium is characterised. On the contrary, to the intellectual activity imparted by opium it adds a corresponding sensitiveness and activity of all the feelings, and of the senses both internal and external. From the effects of opium a man must be roused by shaking and bodily movement. Those of

haschisch are allayed by gentle soothing, and bodily stillness. This drug seems, in fact, to be to the oriental a source of exquisite and *peculiar* enjoyment, which unfits him for the ordinary affairs of this rough life, and with which, happily, we are, in this part of the world, still altogether unacquainted.

It is impossible to form any estimate of the quantity of hemp, of hemp-resin, or of the artificial extract which is now used in different parts of the world for purposes of indulgence. It must, however, be very large, since the plant is so employed in one form or another by probably not less than two or three hundred millions of the human race! Recent statistics of the exports of hemp-resin from Afghanistan alone, indicate the immense quantities of this narcotic which are consumed in the East. There was sent in the year 1876 not less than £86,000 worth through the Khyber Pass into British India.

CHAPTER XIX.

THE NARCOTICS WE INDULGE IN.

THE BETEL-NUT AND THE PEPPERWORTS.

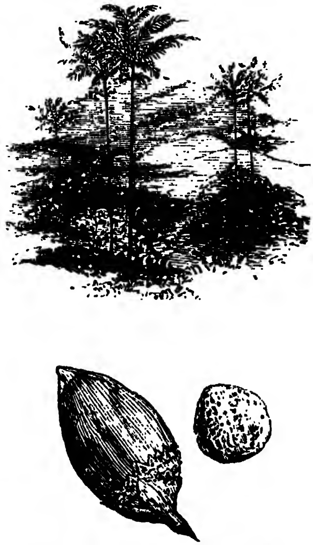
The betel-nut and betel-palm; plantations of, in the East; extensive growth in Sumatra.—How this nut is used, and prepared.—Fondness for the betel in India.—Sensible effects of betel-chewing; its narcotic effects; counteracts opium.—Constituents of the betel-nut; its astringent principle.—Consumption of betel.—Substitutes for betel.—Catechu and gambir extract; extending consumption of the latter.—The pepperworts.—Betel-pepper or pawn—Beauty of the plant, and its importance as an agricultural product.—Mode of cultivation.—Effects of the betel-pepper.—The intoxicating long-pepper or ava.—Chemistry of the pepperworts.—Piperin; its use against fevers.—Grains of Paradise, or malagueta pepper; their use as a spice in Africa and in England—Use in adulterating beer and spirituous liquors.

VIII. Betel-nut.—The Areca or Betel-nut, or Pinang, is the seed of the *Areca Catechu*, one of the most graceful species of palm (fig. 60). On the slopes of the Khasia Mountains in the Himalaya, above the flat Bheels, where palms are numerous, "the cultivated areca raises its graceful head and feathery crown, like an arrow shot down from heaven, in luxuriance and beauty above the verdant slopes"—(Dr Hooker). Almost everywhere in India it is extensively cultivated. It is very abundant in north Bengal and the lower slopes of the mountains of Nepaul. In Ceylon, throughout Malabar, and higher up the coast, it is seen in vast plantations. The produce of these plantations is of great importance. As every one chews betel, the consumption of areca nuts in India is

incredibly great.[1] It forms, therefore, a most important article of traffic.

In the Sunda Islands the areca palm grows wild. In the Philippines, the labourer is paid in betel rolls, as he is with coca-leaves in some parts of Peru; and the betel-nut is one of the most valuable articles of produce in Sumatra. Whole ship-loads are yearly sent off from the latter island to Malacca, Siam, and Cochin-China. The total export was, a few years ago, estimated at 80,000 or 90,000 piculs (each $133\frac{1}{3}$ lb. English), the greater part of which went to China.[2]

Fig. 60.



Areca Catechu—The Betel-nut Palm.
Height, 30 feet.
Fruit, half the natural size.

1°. How the Betel-nut is used.—The betel-nut is about the size of a cherry, slightly pear-shaped, very hard, and externally not unlike a nutmeg of inferior quality. It is chewed along with the leaf of the betel-pepper and a little quick-lime, and a supply of each of these is often carried by the betel-chewer in a box, provided with compartments for the purpose. In describing his visit to the Sultan of Sooloo, Captain Wilkes says: "On the left hand of the Sultan sat his two sons, on the right his councillors, while immediately behind him sat the carrier of his betel-nut casket. The casket was made of filigree silver, about the size of a small tea-caddy, of oblong shape, and rounded at the top. It had three divisions—one for the nut, another for the leaf, and a third for the lime. Next to this official was the pipe-bearer, who did not appear to be held in equal estimation."[3]

[1] See Year-book of Pharmacy, 1874, p. 88.
[2] Ten to twelve millions of pounds.
[3] United States' Exploring Expedition (London edition), ii. 277.

In preparing the betel for chewing in India, the nut is cut into long narrow pieces, and rolled up in leaves of the betel-pepper, previously dusted on one side with moist chunam (the quicklime of calcined shells). In Luçon, one of the Philippines, Meyen found in every corner of the house a little box or dish in which are kept the betel rolls (*buyos*), prepared for the day's consumption; and a buyo is there offered to every one who enters, just as a pinch of snuff or a pipe is with us. In Malacca not only betel-pepper and lime but also gambir contribute to the buyos. Their taste is burning and astringent. "Travellers, and those who work in the open air, carry the buyos for the day in little boxes or bags, as the Peruvians do their coca. The preparation of the betel falls on the female members of the family, who, during the forenoon, may generally be seen lying on the ground and making buyos. The consumption of these is very great. Every one who can afford it puts a fresh buyo in his mouth every hour, which he can chew and suck for half an hour at least."[1] Persons who have lost their teeth have the ingredients ground up into a paste, so as to render chewing unnecessary.

The fondness for the betel in these Eastern countries amounts to something like a passion. It is spoken of with enthusiasm. Many would rather forego both meat and drink than their favourite betel—(Blume). The Tagali maidens regard it as a proof of the uprightness of the intentions of a lover, and of the strength of his affection, if he take the buyo from his mouth—(Meyen). The betel-nut is to the Eastern Archipelago what the coca is to eastern Peru. *Areca Dicksoni*, found wild in Malabar, furnishes an inferior betel for the poorer classes.

2°. Effects of the Betel-nut.—The visible effects of the betel are, that it promotes the flow of the saliva, and lessens the perspiration from the skin. It tinges the saliva red; so that when spit out, it falls on the earth like blood. It gives a red colour to the mouth, teeth, and lips, which, though at first sight disgusting to Europeans, is by the natives considered ornamental. It imparts also an agreeable odour to the breath, and is supposed to fasten the teeth, cleanse the gums, and cool the mouth. The juice is usually, but not always, swallowed.

[1] Meyen—Geography of Plants (Ray Society), p. 352.

Its effects as a narcotic have not been so clearly detailed. To persons not accustomed to it, the nut is powerfully astringent in the mouth and throat, and the quicklime often removes the skin, and deadens for a time the sense of taste. But it causes giddiness when chewed to any extent. On those who are accustomed to use it, however, the betel produces weak but continuous and sustained exhilarating effects. And that these are of a most agreeable kind, may be inferred from the very extended area over which the chewing of betel prevails among the Asiatic nations. In the damp and pestilent regions of India, also, where the natives live upon a spare and miserable diet, it is really very conducive to health. Part of its healthful influence in fever-breeding districts is probably to be ascribed to the pepper-leaf which is chewed along with the betel-nut.

Its alleged effect in rousing persons who are under the influence of opium, as tea counteracts that of spirituous liquors, is somewhat remarkable. During the visit of Captain Wilkes to the Sultan of Sooloo, he had the opportunity of seeing the betel used for this purpose. The Sultan's son, shortly after taking a few whiffs from the opium-pipe, was entirely overcome, and became stupid and listless. When but partially recovered from the stupor, he called for his betel-nut, *to revive him by its exciting effects.* This was carefully chewed by his attendant to a proper consistency, moulded into a ball, and then slipped into his mouth.

3°. CONSTITUENTS OF THE BETEL-NUT.—The chemistry of the betel-nut is quite obscure. It is very astringent, and abounds in a peculiar species of tannin, which is extracted in India by boiling the nut in water, and is brought to this country under the name of *catechu.* In the moist, relaxing climates of the East, this strongly astringent substance acts beneficially upon the system. To it are probably to be ascribed some of the good effects experienced by Perron, who states that he "preserved his health during a long and difficult voyage, by the habitual use of betel; while his companions who did not use it died mostly of dysentery."

But the ordinary and understood action of a merely astringent substance does not account for the giddiness caused by the betel-nut in a young chewer, nor for the gentle intoxication it produces in all. These properties seem to imply the

presence in the nut of some narcotic ingredient which is as yet unknown. From the circumstance of no such substance having been yet discovered in the nut, some writers are inclined to ascribe the intoxicating influence of the buyos altogether to the pepper-leaf in which the nut is enclosed. Upon this point, however, we must suspend our judgment until the chemist has had an opportunity of submitting both nut and leaf to a rigorous chemical examination. My own opinion is, that the coveted effect upon the system is the result of the combined influence—first, of the constituents of the nut; second, of those of the fresh pepper; and, third, of substances which are produced or evolved in the mouth in consequence of the chemical action of the lime and of the saliva upon the ingredients of both nut and leaf. Upon all this, light will no doubt be thrown before long time elapses.

4°. CONSUMPTION OF BETEL.—We have no means of estimating the absolute quantity of this nut which is consumed yearly by the Asiatic nations, but it must be very great. It is chewed by probably not less than fifty millions of men! If we allow to each chewer ten pounds' weight a-year, which is less than half an ounce a-day, this would give the enormous consumption of five hundred millions of pounds' weight every year! Only tobacco, among the narcotics in common use, is used in larger quantity than this.

The small quantity of the betel-nut imported into this country is mainly converted into tooth-paste, or into charcoal for tooth-powder, probably from some imaginary idea that it is superior for this purpose to other kinds of charcoal. Areca nuts in powder have been used as a vermifuge in veterinary practice.

IX. SUBSTITUTES FOR BETEL.—As substitutes for the betel-nut, astringent extracts are coming into extensive use in the East. Thus—

a. The *catechu*, which is extracted, as above described, by boiling the areca nut, is extensively chewed in India, in place of the nut itself. It is there called *cashu*, and is known in this country by the older name of *Terra Japonica*.

In the north of India, towards the foot of the Himalayas, a similar catechu is extracted by boiling the wood of the

Mimosa Catechu, which grows wild there and in Ava. This is chewed in the same way as the areca catechu.

b. The *gambir* extract—which greatly resembles the *Terra Japonica*, but has a sweetish taste, and is still more astringent—is another substitute for the nut. The *Uncaria gambir* is a shrub six or seven feet in height, the leaves and shoots of which, by boiling with water, yield the gambir extract. In the island of Sumatra, in Java, and the other Dutch colonies, in India, Malacca, Singapore, and many other localities, large plantations of these shrubs exist. The leaves are gathered from two to four times a-year, and are boiled with water for five or six hours in iron kettles. The decanted liquor is then thickened by further boiling, and poured into moulds, when it hardens. This extract is of a blackish-brown colour, has at first a sweetish taste and a pleasant aromatic flavour, which afterwards becomes astringent and bitter. It is chewed by the Malays in Sumatra, and in the Dutch colonies generally, in place of, or along with, the betel-nut; and the use of it is said to be rapidily extending throughout India.

Very salutary virtues are ascribed to the gambir extract, and it is said especially to assist digestion. It is no doubt a mixed substance, containing several chemical ingredients. It has not, however, been chemically investigated; so that what it contains in addition to the astringent principle, or whether it possesses any narcotic virtues, we have as yet no means of knowing. The quality, and probably the composition, varies in different localities. But as the plant belongs to the same natural order as coffee and cinchona, it probably contains like them an active alkaloid. The most esteemed samples are those from Penang and the coast of Bengal.

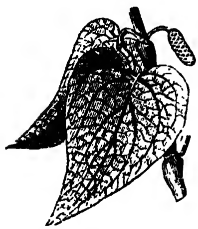
In 1833 the quantity of this substance produced on the island of Penang alone amounted to 70,000 piculs, and in Singapore to 20,000—or together, to 10,000,000 lb.—(Meyen). In 1874 no less than 16,728 tons of gambir were imported into England, chiefly for tanning and dyeing.

X. The Pepperworts.—Various species of pepper are known to be possessed of narcotic properties, and several of these are in constant and most extensive use in tropical countries. The pepperworts are for the most part climbing

plants, and where they grow wild, frequently strangle the tree they embrace.

1°. THE BETEL-PEPPER OR PAWN.—The leaf of the betel-pepper (*Chavica betle* and *C. Siriboa*), fig. 61, is always chewed along with the betel-nut, as above described. The almost universal use of the betel-nut makes the culture of this pepper one of great importance in the East, especially in the neighbourhood of large towns. Every person who possesses a little bit of land usually grows the leaves for his own consumption; and it may often be seen clinging round the stems of the beautiful betel-palms which overshadow their dwellings. But in the towns, incredible quantities are every day sold in the markets, and piles of the leaves, three or four feet high, are carried about in baskets. The plantations of betel-pepper are laid out like our bean-fields, but the plants stand eighteen inches apart, and their large beautiful heart-shaped leaves give the whole field a bright green colour, such as belongs to few other plants. They require much water, and are allowed to climb on poles like hops for the first eighteen months. They are then detached, and are directed round fast-growing young trees, which have meanwhile been planted between them. The leaves may be gathered in the third or fourth year, and the plants bear for six or seven years, after which they die and must be replaced—(MEYEN).

Fig. 61.



Chavica betle—The Betel-leaf, or Betel-pepper. Scale, 1 inch to 3 inches.

In northern India, and towards the Himalayas, the plant, though in almost equal demand, cannot be cultivated in the open fields, and is therefore raised under cover where the atmosphere is sufficiently moist. Dr Hooker, when travelling on the banks of the Mahanuddee, towards the foot of the Himalayas, observed some curious low sheds erected for the growth of pawn or betel-pepper. These sheds were 20 to 50 yards long, 8 or 12 broad, and scarcely 4 feet high. They were of bamboo, wattled all round, and over the top. Inside the sheds slender upright rods were placed a few feet apart, up which the pepper plants climbed, and speedily filled the place with their deep green glossy foliage. The native enters every morning and carefully cleans the plants. Great atten-

tion is paid to them, as they would not live twenty-four hours if exposed to the open air; but the cultivation is, nevertheless, very profitable. This mode of culture extensively prevails.

I have already described the effects of the betel-chewing in general. What portion of these effects is due to the pepper-leaf in which the nut is wrapped up, has not been experimentally ascertained. But as other varieties of pepper, which are used alone, are known to possess narcotic properties, some are inclined to ascribe the greater part of the peculiar influence of betel-chewing to this pepper-leaf. I do not coincide with this opinion. As I have already explained, the observed effects are, in the present state of our knowledge, to be ascribed rather to the conjoined influence of the constitutents of both nut and leaf, and to the chemical action of the quicklime used along with them, and of the saliva upon both.

2°. THE INTOXICATING LONG-PEPPER.—The narcotic effects of the Ava, or *Piper methysticum* (fig. 62), are more certain and more celebrated.

This plant has a thick, woody, rugged, aromatic wood-stalk, which, when reduced to a pulp and then steeped in water, forms an intoxicating beverage.[1] This is in extensive use among the South Sea Islanders, both as a medicine and as an inebriating indulgence. It possesses a recognised narcotic influence, which is derived from some ingredient contained in the root. The same ingredient probably exists in the leaves, which are chewed along with the betel-nut instead of those of the betel-pepper.

The roots and thickest parts of the stems of long-pepper, cut into small pieces and dried, form a considerable article of commerce all over India, under the name of *Pipula moola;*[2] but I am not aware if they are used for narcotic or intoxicating purposes.

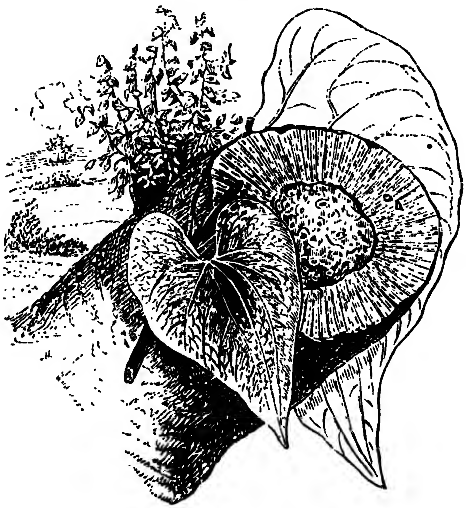
The half-dozen species of pepper or pepperworts which have been examined chemically, appear to contain an aromatic oil allied to turpentine, and two active bases or alkaloids. One of these latter is a beautifully crystalline substance called *piperine;* the other, known as *chavicine,*

[1] See "The Liquors we Ferment."

[2] Pereira—Materia Medica, p. 1260.

does not crystallise. Piperine has but little taste when pure, and acts mainly as an irritant of the sensory nerves:

Fig. 62.



Piper methysticum—The Ava Pepper shrub.
Scale, 1 inch to 3 feet.
Leaf, 1 inch to 2 inches. Outline of leaf, natural size.
Part of stem and root, showing section, natural size.

chavicine, on the contrary, has a very fiery taste. All the three constituents mentioned—the oil, the chavicine, and the piperine—exercise a beneficial action in cases of intermittent fever; and to this action we are safe, I think, in ascribing a portion at least of their salutary influence in tropical regions. While in betel-chewing the astringent principle of the nut checks the tendency to internal relaxation, the fever-chasing principles of the pepper-leaf preserve the health amid the steaming vapours which the hot sun draws forth from swamps and jungles and irrigated paddy-fields.

3°. Grains of Paradise.—Guinea grains or Malagueta pepper are the seeds, not of a pepperwort, but of a species of Cardamom (*Amomum Melegueta*), a plant belonging to the Ginger order. They are imported from the coast of Guinea, where they are used by the natives as a spice for seasoning

their food, and are held in great esteem. The seeds are small and angular, and consist of a glossy dark-brown husk, enclosing a perfectly white kernel, which has a hot, pungent, peppery taste. In Africa they are considered to be exceedingly wholesome. No less than fourteen species of this genus Amomum yield aromatic fruits in use as flavourers or stimulants in different countries—China, Siam, Sierra Leone, Java, &c. Cardamoms are the fruit of a closely allied plant, *Elettaria Cardamomum*, and are imported from Madras, Malabar, &c. The medieval spice, *Galangal*, was identified in 1870 as the root of *Alpinia officinarum*, a plant belonging, like *Elettaria* and *Amomum*, to the Ginger order.

Grains of paradise were also very anciently in use as a spice in English cookery. The ancient fee-favour of the city of Norwich is twenty-four herring-pies, each containing five herrings, to be carried to Court by the lord of the manor of Carleton. In 1629 these pies were described as being seasoned with half a pound of ginger, half a pound of pepper, a quarter of a pound of cinnamon, one ounce of cloves, one ounce of long-pepper, half an ounce of *grains of paradise*, and half an ounce of galangals. I am not aware that they are now in use anywhere in England for the seasoning of food, though the fruits and seeds of many of the species of Amomum are employed as drugs.

About 40,000 lb. of this seed were for a long time imported yearly into England; and we cannot learn that the quantity has lessened of late. With the exception of what is used in veterinary medicine, all this is said to be employed for the purpose of flavouring cordials or of imparting a fictitious appearance of strength to malt and spirituous liquors. By 56 Geo. III. c. 58, "no brewer or dealer in beer shall have in his possession or use grains of paradise, under a penalty of £200 for each offence; and no druggist shall sell the substance to a brewer under a penalty of £500 for each offence." Nevertheless, it is both sold and used, principally along with capsicum and juniper-berries, to give a hot strong flavour to London gin; and along with several bitters, to give a relish and warmth to country beer. In passing through Staffordshire some time ago, I was assured by a person connected with a large manufactory, that he had himself seen, in a druggist's shop, as much as 10 lb. of grains of paradise sold

to a single customer, for putting into beer. In September 1854, six retail brewers of Bilston, Staffordshire, were fined £50 each at the Wolverhampton petty sessions for having in their possession and using grains of paradise.

The effect of hot substances like this in giving to liquors the appearance of strength is illustrated by the qualities of a drink prepared in some of the Turkish provinces. A greatly esteemed liquor is there made by digesting mint and pimento in water. This liquor possesses so much of what is taken for alcoholic strength, that the person who drinks it for the first time supposes he has swallowed "the most ardent alcohol." No wonder the iron smelters and puddlers of Staffordshire drink beer three whole days out of the fortnight, if their thirst be provoked by grains of paradise, so that the more they drink the thirstier they become! It is satisfactory to think, however, that though a provoker to drunkenness, this adulteration is not known to be poisonous in itself. Cardamoms have been found to contain a considerable quantity of a pungent essential oil.

CHAPTER XX.

THE NARCOTICS WE INDULGE IN.

COCA.

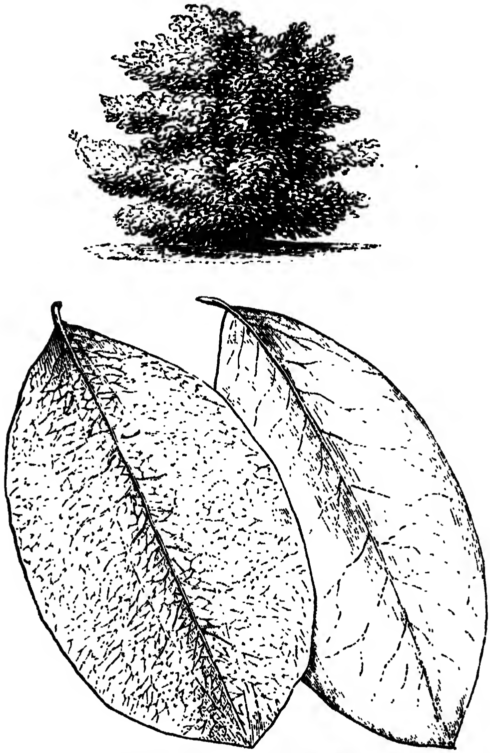
Coca, the narcotic of the Andes: description of the plant; mode of cultivation.—Ancient use of the coca-leaf.—Its necessity to the Indian of Peru; how he uses it.—Its remarkable effects.—Melancholy temperament of the Indian.—Testimony of Von Tschudi and of Dr Weddell.—General effects of the coca-leaf.—Intolerable craving of the confirmed "coquero."—Evil effects of the coca-leaf.—Testimony of Pöppig and other travellers.—Opinions of old Spanish writers.—Indian reverence for the plant.—Its characteristic effects.—Lessens the necessity for ordinary food.—Prevents difficulty of breathing in ascending hills.—Experience and testimony of Von Tschudi.—Its introduction into Europe recommended.—Chemical history of the coca-leaf.—The odoriferous resin.—The bitter principle.—The tannic acid.—How the coca-leaf acts.—Difficulties as to its action.—How it resembles tea, the hop, hemp, and opium.—Like opium, it sustains and inclines to retirement.—Consumption of coca.—Probable extent and money value of the yearly growth of coca.

Coca, the narcotic of the Andes, is not less interesting than the narcotics of the East, either in its social or in its physiological relations. It is little known in Europe—its use as an indulgence being in a great measure confined to the native Indians of Bolivia, Peru, and Brazil.

The *Erythroxylon Coca* is a bush which attains the height of six or eight feet, and resembles the black thorn in its small white flowers and bright green leaves (fig. 63). It is a native of the tropical valleys which occur on the eastern slope of the Andes, in Bolivia and Peru, and it still grows wild in many parts of these countries. That which is used by the people,

however, is chiefly the produce of cultivation. In the inhabited parts of the above valleys it forms an important agricultural crop. Like our common thorn, it is raised in

Fig. 63.



Erythroxylon Coca—The Coca-leaf plant.
Scale, 1 inch to 3 feet.
Coca-leaf, natural size, showing the upper and under sides of the leaf. The under side exhibits the remarkable arched line on each side of the midrib by which this leaf is distinguished.

seed-beds, from which it is planted out into regularly arranged coca-plantations. The steep sides of the valleys, as high up as 8000 feet above the level of the sea, where the mean temperature is from 64° to 68° Fahr., are often covered with these plantations of coca. They are arranged in terraces rising

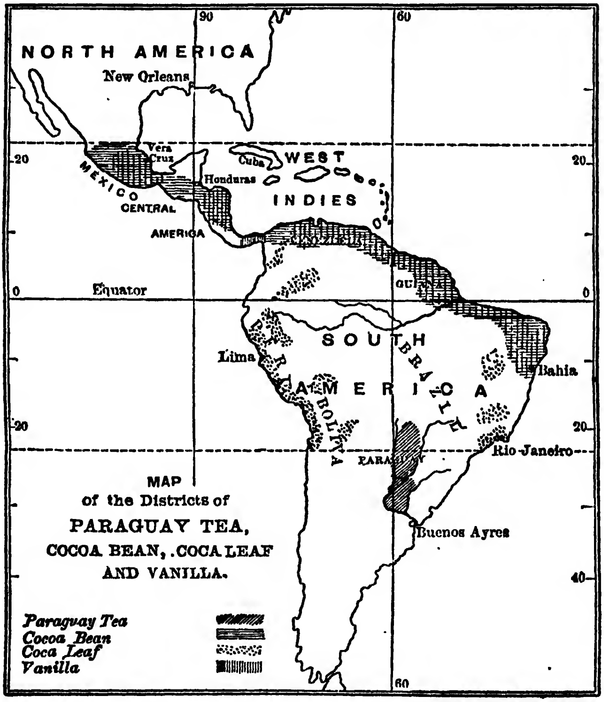
above one another, as in the vineyards of Tuscany and the Holy Land. A moist air and shade for the young plants are secured by sowing maize between the rows, or arbours of palm-trees are constructed as a shade. The province of Yongas is the principal seat of this cultivation in Eastern Bolivia. In three years the bushes come into full bearing, and in favourable localities yield three, and, where irrigation is used, even four crops of leaves in a year. The leaves are about the size of those of the cherry-tree; and when ripe enough to break on being bent, they are collected by the women and children, and dried in the sun. A hundred plants yield an arroba, 26 lb., at a crop. The total produce averages about 800 lb. of dry leaves per English acre. It is sometimes one-half more, but often also very much less. When nearly dry they emit an odour similar to that of new-made hay, in which much melilot or sweet-scented vernal grass is contained; hence they occasion headaches among new-comers, as haymaking does with delicate persons among ourselves.

These sun-dried leaves form the coca of commerce. When of good quality they are of a pale-green colour. Dampness causes them to become dark-coloured, in which state they are less esteemed, and their smell less agreeable. If they heat through dampness, they become altogether useless. Their taste is not unpleasant; it is slightly bitter and aromatic, and resembles that of green tea of inferior quality. It becomes more piquant and agreeable when a sprinkling of quicklime or plant-ashes is chewed along with them. The alkaline ashes of the *Chenopodium Quinoa* are commonly used for this purpose.

1°. Ancient use of the Coca-leaf.—The use of this plant among the Indians of South America dates from very remote periods. When the Spanish conquerors overcame the native races of the hilly country of Peru, they found extensive plantations of a herb called coca[1] (*see* Map). And they observed among these races the singular custom of chewing the leaves of this plant during frequent short periods of repose, especially set apart for the purpose. So general, indeed, was the use of this plant, and so common the demand for it, that it

[1] The word *Coca* is derived from the Aymara (Indian) word Khoka, signifying "plant," in the same way as in Paraguay the indigenous tea-plant is called *Yerba*, "*the* plant" *par excellence*.

formed the usual money, or medium of exchange, in Peru.[1] The practice of using this plant was even then ancient among the Indian races, and its origin was lost in the mists of remote antiquity. After the introduction of gold and silver money it became the principal article of traffic. Its cultivation was a care of the native governments during the reign of the Incas,



and it continues equally prevalent to the present day. The beloved leaf is still to the Indian of the mountains the delight, the support, and in some measure the necessity, of his life. He is never seen without the leathern pouch (his *chuspa*) to contain his coca-leaves, and his little gourd-bottle to hold

1 As tobacco does now among the Damaras, Ovampo, and other tribes of South-Western Africa, visited by Mr Galton.—See his Tropical South Africa, p. 206.

powdered unslacked lime—or, if he is a Bolivian, the alkaline ashes of the quinoa, of the musa root, or of certain other plants.

When preparing to *acullicar*, or chew, he first makes himself as comfortable as circumstances will permit. He lays down his burden, if he has one; he seats himself, and putting his chuspa between his knees, he pulls out, one by one, the leaves which are to form his new ball. The attention he gives to this operation is worthy of remark. The satisfaction with which he dips his hand into the midst of the leaves of a full chuspa, and the regret with which he looks upon his little bag when it is nearly empty—these little things prove that to the Indian the custom is a source of real happiness, and not the mere consequence of a want—(WEDDELL). Always three, and sometimes four times a-day, he rests from his mining or other labour, or pauses in his journey, and lays down his burden, to chew in quiet the beloved leaf.

When riding, or walking, or labouring, the leaves have little effect. As with opium and hemp, stillness and repose are indispensable to his full enjoyment of the feeling of luxury it produces. In the shade of a tree he stretches himself at ease, and from time to time puts into his mouth a few leaves rolled into a ball (an *acullico*), and after each new supply a little unslacked lime on the end of a slip of wood moistened and dipped into his lime-flask. This brings out the *true taste* of the leaf, and causes a copious flow of greenish-coloured saliva, which is partly rejected and partly swallowed. When the ball ceases to emit juice it is thrown away, and a new supply is taken.

The interval of enjoyment conceded to the labouring Indian lasts from fifteen minutes to half an hour, and is generally wound up by the smoking of a paper cigar. Repeated three or four times a-day, his average consumption of coca is an ounce or an ounce and a half in the twenty-four hours, and on holidays double that quantity. The owners of mines and plantations have long found it for their interest to allow a suspension of labour three times a-day for the *chaccar*, as it is called; and the Indian speedily quits an employer who endeavours to stint or deprive him of these periods of indulgence. During these periods his *phlegm* is something marvellous. No degree of urgency or entreaty on the part of the

master or employer will move him; while the confirmed *coquero*, when under the influence of the leaf, is heedless of the thunderstorm which threatens to drown him where he lies, of the roar of approaching wild beasts, or of the smoking fire which creeps along the grass, and is about to suffocate or scorch him in his lair.

The Indians of the Peruvian Andes are subject to fits of melancholy, or are generally perhaps of a gloomy temperament. "In their domestic relations," says Von Tschudi, "the Indians are unsocial and gloomy. Husband, wife, and children live together with but little appearance of affection. The children seem to approach their parents timidly, and whole days sometimes elapse without the interchange of a word of kindness between them. When not engaged in outdoor work, the Indian sits gloomily in his hut, chewing coca, and brooding silently over his own thoughts." [1]

Dr Weddell, who travelled in Bolivia, bears a similar testimony in regard to the appearance and manners of these people. "It is difficult," he says, "to have lived for any time among these men without being struck by the expression of concentrated melancholy which can be read upon their features, and which seems to speak of an undefined but constant suffering. This physiognomy is, above all, remarkable among the Aymaras, whose character is also more taciturn than that of the Quichuas, who inhabit along with them the table-lands of the Andes." [2]

It does not appear, however, that the coca adds to the gloom of the unhappy Indian; on the contrary, he takes it to relieve himself for the time from the peculiarities of his temperament. Silence and abstraction are necessary to the enjoyment, but the use of it makes him cheerful; and it is to the unhappy, often oppressed, and always poor Peruvian, the source of his highest pleasures. It has come down to him as a relic of the ancient enjoyments of his people, and during the fantasy it produces, he participates in scenes and pleasures from which in common life he is altogether excluded. Dr Weddell very sensibly remarks, that, as a relic of the past, he attaches "superstitious ideas to the coca, which must triple, in his imagination, the benefits he receives from it,"

[1] Travels in Peru, 1838 to 1842, p. 450. London, 1847.

[2] Weddell—Voyage dans le Nord de la Bolivie, p. 61. Paris, 1853.

and that its value to him is further enhanced by its being the "sole and only distraction which breaks the incomparable monotony of his existence."

2°. General effects of the Coca-leaf.—The coca-leaf acts differently according to the way in which it is used. When infused and drunk like tea, it produces a gentle excitement, followed by wakefulness; and, if taken strong, retards the approach of hunger, prevents the usual breathlessness in climbing hills, and, in large doses, dilates the pupil and renders the eye intolerant of light. It is seldom used in this way, however, but is commonly chewed in the form of a ball or quid, which is turned over and over in the mouth as is done with tobacco. In this way its action is more gradual and prolonged than when the infusion only is taken. It is also very different in its character, because the constant chewing, the continued action of the saliva, and the influence of the lime or ashes chewed along with it, extract from the leaf certain other active constituents which water alone does not dissolve when it is infused after the manner of tea.

The cultivation and use of the coca have extended from the slopes of the Andes eastward, to different parts of Brazil, and to the river of the Amazons. But here it is used somewhat differently. The leaves are dried and reduced to powder in a wooden mortar along with the ash of the leaves of *Cecropia peltata*, and in this mixed state are preserved for use. From time to time a portion of this greenish-grey powder is introduced into the mouth, especially when it is desired to overcome hunger or drowsiness. It augments the secretion of saliva, produces a sensation of fulness and warmth in the mouth, stills hunger, and increases bodily activity.

We have no detailed account, by an actual chewer of the leaf, of the *special* effects which it produces; but these must be very seducing—for, though long since stigmatised, and still very generally considered as a degrading, purely Indian, and therefore despicable vice, many white Peruvians at Lima and elsewhere retire daily at stated times to chew the coca. Even Europeans in different parts of the country have fallen into the habit. A confirmed chewer of coca is called a "coquero," and he is said to become occasionally more thoroughly a slave to the leaf than the inveterate drunkard is to spirituous liquors.

Sometimes the coquero is overtaken by a craving which he cannot resist, and he betakes himself for days together to the silence of the woods, and there indulges unrestrained in the use of the weed. Young men of the best families in Peru become sometimes addicted to this extreme degree of excess, and are then considered as lost. Forsaking cities and the company of civilised men, and living chiefly in woods or in Indian villages, they give themselves up to a savage and solitary life. Hence the term, a *white coquero*, has there something of the same evil sense as irreclaimable drunkard has with us.

The chewing of coca gives "a bad breath (abominable, according to Weddell), pale lips and gums, greenish and stumpy teeth, and an ugly black mark at the angles of the mouth. The inveterate coquero is known at the first glance. His unsteady gait, his yellow skin, his dim and sunken eyes encircled by a purple ring, his quivering lips, and his general apathy, all bear evidence of the baneful effects of the coca-juice when taken in excess."—(VON TSCHUDI.)

Its first evil effect is to weaken the digestion; it then gradually induces a disease locally named the *opilacion*. Biliary affections, with all the painful symptoms which attend them in tropical climates, and, above all, costiveness, are frequent and severe. The appetite becomes exceedingly uncertain, till at length the dislike to all nourishment is succeeded by an inordinate appetite for animal food. Then dropsical swellings and boils come on; and the patient, if he can get it, flies to brandy for relief, and thus drags out a few miserable years, till death relieves him.[1]

These descriptions are sufficiently repulsive, but they exhibit only the dark side of the picture. A similar representation could be truthfully made of the evil effects of wine or beer in too numerous cases, without thereby implying that these liquors ought either to be wholly forbidden, or of our own accord entirely given up. Where coca was most in use, Dr Weddell states that he met with none of the extreme cases mentioned by Pöppig. The chewing of the leaf, he says, produces ill effects sometimes upon Europeans who have not contracted the habit in their youth. And in two or

[1] Pöppig—Reise in Chile, Peru und auf dem Amazon Ström, 1827 to 1832, chap. iv.

three cases which came under his observation, he ascribed to the abuse of it the production of a "peculiar aberration of the intellectual faculties characterised by hallucinations." Von Tschudi also, as the sum of his inquiries, says: "Setting aside all extravagant and visionary notions on the subject, I am clearly of opinion that the moderate use of coca is not merely innoxious, but that it may even be very conducive to health. In support of this conclusion, I may refer to the numerous examples of longevity among Indians who, almost from the age of boyhood, have been in the habit of masticating coca three times a-day. Cases are not unfrequent of Indians attaining the great age of 130 years; and these men, at the ordinary rate of consumption, must in the course of their lives have chewed not less than 2700 lb. of the leaf, and yet have retained perfect health. Even the Indian coquero, who takes it in excess, reaches the age of fifty years. It is consumed both more abundantly, however, and with less baneful results, in the higher Andes than in the lower and warmer regions."

It is certain that the Peruvian Indians have always ascribed to it the most extraordinary virtues. Clusius, writing in 1605, says that when he asked the Indians why they always had the coca in their mouths, the answer was, that, when using it, neither hunger nor thirst annoyed them, while their strength and vigour were confirmed; and Dr Unanui, in the title of his Dissertation on the plant (Lima, 1794), speaks of it as "La famosa planta del Peru nombrada coca."

At the present day the Indians still regard it as something sacred and mysterious. This impression they have probably inherited as a fragment of their ancient religion, for in all the ceremonies, whether warlike or religious, of the time of the Incas, the coca was introduced. It was used by the priests either for producing smoke at the great offerings to the gods, for throwing in handfuls upon the sacrifice, or as the sacrifice itself.

"During divine worship the priests chewed coca-leaves, and unless they were supplied with them, it was believed that the favour of the gods could not be propitiated. It was also deemed necessary that the supplicator for divine grace should approach the priests with an acullico in his mouth.

It was believed that any business undertaken without the benediction of coca-leaves could not prosper, and to the shrub itself worship was rendered. During an interval of more than three hundred years Christianity has not been able to subdue this deep-rooted idolatry, for everywhere we find traces of belief in the mysterious powers of this plant. The excavators in the mines of Cerro de Pasco throw chewed coca on hard veins of metal, in the belief that it softens the ore and renders it more easy to work. The origin of this custom is easily explained, when it is recollected that in the time of the Incas it was believed that the *cozas*—the deities of metals—rendered the mountains impenetrable if they were not propitiated by the odour of coca. The Indians, even at the present time, put coca-leaves into the mouths of dead persons, to secure to them a favourable reception on their entrance into another world; and when a Peruvian Indian on a journey falls in with a mummy, he, with timid reverence, presents to it some coca-leaves as his pious offering."—(Von Tschudi).

3°. Characteristic effects of the Coca-leaf.—Even those Europeans who are best acquainted with the Indian races, and have seen most of the action of this plant upon them, do not deny that, in addition to the ordinary properties of a weak narcotic, the coca-leaves possess two extraordinary qualities not known to coexist in any other substance. These are—

First, That when chewed they lessen the desire, and apparently the necessity also, for ordinary food. They not only enable the chewer, as brandy and opium do, to put forth a greater nervous energy for a short time, but actually, with the same amount of food, perseveringly to undergo more laborious fatigue or longer-continued labour. With a feeble ration of dried maize, or barley crushed into flour, the Indian, if duly supplied with coca, toils under heavy burdens, day after day, up the steep slopes of the mountain-passes; or digs for years in the subterranean mines, insensible to weariness, to cold, or to hunger. He believes, indeed, that it may be made a substitute for food altogether; and an instance given by Von Tschudi seems almost to justify this opinion.

"A cholo of Huari, named Hatan Huamang, was employed

by me in very laborious digging. During the five days and nights he was in my service he never tasted any food, and took only two hours' sleep each night. But at intervals of two and a half or three hours he regularly chewed about half an ounce of coca-leaves, and he kept an acullico continually in his mouth. I was constantly beside him, and therefore I had the opportunity of closely observing him. The work for which I engaged him being finished, he accompanied me on a two days' journey of twenty-three leagues across the level heights. Though on foot, he kept up with the pace of my mule, and halted only for the *chaccar*. On leaving me, he declared he would willingly engage himself again for the same amount of work, and that he would go through it without food, if I would but allow him a sufficient supply of coca. The village priest assured me that this man was sixty-two years of age, and that he had never known him to be ill in his life."

How this remarkable effect of the coca is to be accounted for, in accordance with received notions on the subject of animal nutrition, it is not easy to see. Dr Weddell, who is less decided in his praise of the virtues of the leaf, says that the facts in favour of the opinion that it is capable of supporting the strength, in the absence of all other nourishment, have been advanced by so many persons worthy of credit, that we must push our scepticism very far if we are to doubt them. He asserts, however, that, as commonly used, coca does not *satisfy the appetite*. The Indians who accompanied him in his tour, though they chewed all day, yet at night ate like hungry men, and sometimes at a single meal swallowed as much as would serve him two days. The power of enabling them to support abstinence, therefore, is all he is willing, from his limited experience, to concede to the plant. It produces, he says, a peculiar excitement, slow and sustained; not, like that of tea and coffee, exercised chiefly on the brain, but diffused generally over the nervous system.

The least we can concede to the plant, therefore, seems to be, that it enables the body to feed upon itself, so to speak, for a length of time, without the hunger-pains and weakness which usually accompany the prolonged abstinence from ordinary food.

Second, The other extraordinary property of the leaf is that,

either when chewed or when taken in the form of infusion, like tea, it prevents the occurrence of that difficulty of respiration which is usually felt in ascending the long and steep slopes of the Cordillera and the Puna.

"When I was in the Puna," says Von Tschudi, "at the height of 14,000 feet above the level of the sea, I drank always, before going out to hunt, a strong infusion of coca-leaves. I could then, during the whole day, climb the heights and follow the swift-footed wild animals, without experiencing any greater difficulty of breathing than I should have felt in similar rapid movements on the coast. Moreover, I did not suffer from the symptoms of cerebral excitement or uneasiness which other travellers have experienced. The reason perhaps is, that I only drank the decoction on the cold Puna, where the nervous system is far less susceptible than in the climate of the forests beneath. However, I always felt a sense of great satiety after taking the coca infusion, and I did not feel a desire for my next meal until after the time at which I usually took it."

The reason of this action of the leaf is not less difficult to make out than that of its alleged strength-sustaining capabilities.

When the Spanish conquerors took possession of Peru, the Indians and all their customs were treated by them with equal contempt; but everything connected with their religion was especially denounced by the Spanish priests. Hence the use of coca was condemned and forbidden.

A council of the Church denounced it in 1567 as a "worthless substance, fitted for the misuse and superstition of the Indians;" and a royal decree, in 1569, condemned the idea that coca gives strength, as an "illusion of the devil." But these fulminations were of no avail. The Peruvians still clung to their esteemed national leaf; and the owners of mines and plantations, discovering its efficacy in enabling their slaves to perform the heavy tasks they imposed upon them, soon became its warm defenders. Even churchmen at last came to regard it with indulgence, and, stranger still, to recommend its introduction into Europe.

One of the warmest advocates of the plant was the Jesuit Don Antonio Julian, who, in a work entitled, 'Perla de America,' laments that coca is not introduced into Europe

instead of tea and coffee. "It is," he observes, "melancholy to reflect that the poor of Europe cannot obtain this preservative against hunger and thirst, and that our working people are not supported by this strengthening plant in their long-continued labours."

Dr Don Pedro Nolasco Crespo, again, in a treatise published in 1793, insisted upon the advantages which might be derived from the introduction of the plant into the European navies. Von Tschudi has also recommended it as fitted "to afford a nutritious refreshment to seamen in the exercise of their laborious duties, and to counteract the unwholesome effect of salt provisions." And lastly, Professor Schlechtendal, after commending coca as tonic, soothing, and nutritive—as preventing weakness of the stomach, and the affections, colic and hypochondria, to which such weakness gives rise,—adds that, "without doubt, the leaves might be usefully employed in Europe."

With all this testimony in its favour, we may, I think, dismiss those fears of the coca-leaf which old Spanish prejudices awakened, and which representations like those of Pöppig have tended to perpetuate in England. It has lately been tried in England and the Continent with a measure of success. But in our climate, and after so long a sea-voyage, its effects seem weaker than in its native country.

4°. Chemical History of the Coca-leaf.—It is known to contain at least three different constituents, upon the joint action of all of which the observed effects of the leaf probably depend. These are—an odoriferous resinous substance, a bitter principle, and a species of tannic acid.

First, The odoriferous resin.—As they reach this country, the leaves are coated with a resinous or waxy substance, which is only in a limited degree soluble in water, but which ether readily dissolves. When digested in ether for the purpose of extracting this substance, a beautiful dark-green solution is obtained, which, on being evaporated in the open air, leaves a brownish resin, possessed of a powerful, peculiar, and penetrating odour. When exposed for a length of time to the air, this resinous matter diminishes in quantity, and gradually loses the whole of its smell, leaving a fusible, nearly inodorous, matter behind. Ether therefore extracts at least two substances from the leaf, one of which is very volatile,

and has a powerful odour. It is probable that in this volatile substance the narcotic qualities of the leaf reside. And this is consistent with the fact, that the leaves gradually lose their smell and virtue, and, after twelve months, are generally considered worthless; and with the assertion of those who live in the coca country, that only among them are the real virtues of the leaf ever experienced by the consumer. It is usual to make up the leaves into hard packages, covered with fresh hides, which shrink and compress the whole as they dry. But notwithstanding this close packing, resembling that of hard-pressed hop-pockets, they insensibly give off their volatile ingredients as hops do, and by transport and keeping continually diminish in value and estimation. The volatile resinous matter extracted by ether is therefore one of the most important ingredients of the coca-leaf—(JOHNSTON).

Second, The bitter principle.—We have seen in a preceding chapter[1] that tea and coffee, besides the volatile ingredients to which their aroma is owing, contain a white, bitter, crystallisable substance known by the name of *theine;* and that to this theine the remarkable properties of these beverages are partly to be ascribed. Coca also contains a crystalline bitter principle, which alcohol is capable of dissolving out of the leaves. This substance is a base or alkaloid, and is called *cocaine.* In many particulars and in its physiological action upon the system it resembles *atropine,* the alkaloid of deadly nightshade. It can scarcely be doubted that the effect of the leaf upon the coca-chewer is due in part to the presence of this coca bitter.

Third, Besides these two substances, the coca-leaf contains also a tannic acid, which, like the tannic acid of tea, gives a deep brownish-green colour with what are called *per* salts[2] of iron.

The proportions in which these several known ingredients occur in the leaf have not been exactly determined.

5°. HOW THE COCA-LEAF ACTS.—It will strike the reader that even this imperfect knowledge of the chemistry of the plant shows a singular analogy between the coca-leaf, the hop-flower, and the tea-leaf of China. All contain a volatile, aroma-giving ingredient; in all a bitter principle exists; and

[1] See "The Beverages we Infuse," p. 127.

[2] These are compounds of the *red* or *per*-oxide of iron with acids.

from all of them a tannic acid can be extracted. Yet if, with this small amount of chemical knowledge—aided even by what we know of the action of tea and the hop—we attempt to explain the remarkable effects produced by the coca-leaf, we utterly fail.

How the mere chewing of one or two ounces of these leaves in a day, partly rejecting and partly swallowing the saliva,[1] but wholly rejecting the chewed leaf—how this supports the strength, or can materially nourish the body in the ordinary acceptation of the term, we cannot understand. It cannot *give* much to the body; it must therefore act simply in preventing or greatly diminishing the ordinary and natural waste of the tissues which usually accompanies bodily exertion. As wine and tea act upon the nervous system of the aged, so as to restrain the natural waste to a quantity which the now weakened digestion can readily replace, and thus maintain the weight of the body undiminished,—so it is, probably, with coca. In the young and middle-aged it lessens the waste of the tissues, and thus enables a smaller supply of food to sustain the weight and strength of the body. But it must not be forgotten that if we lessen the natural waste of the body or lessen the daily ration of food, we lessen the sources of power in the body. To keep up the heat and activity of the body, fuel, that is, food which has been assimilated, must be consumed or burnt.

The coca-leaf resembles that of hemp, in the narcotic quality of dilating the pupil, which opium does not possess. But, on the other hand, it resembles opium in the new strength it imparts to the worn and weary body. The Turkish courier, or the Cutchee horseman, under the influence of opium, reminds us of the Peruvian miner or muleteer who has plenty of coca. In spite of fatigue and exhaustion, both compel their failing limbs to new exertion, and, unconscious of new pain, accomplish most wonderful labours. And in the proneness of the coca-eater to a solitary life, we recognise an influence of this herb similar to that which opium exercises upon those who have experienced its highest enjoyments. It is alone and in retirement that the Eastern opium-eater finds his

[1] Dr Weddell states that the saliva is *never rejected*; and being a later authority than Von Tschudi, whom I have followed in the text, he is probably correct.

greatest pleasure. And in our own less sunny climate the same inclination appears to exist. "Markets and theatres," says De Quincey, "are not the appropriate haunts of the opium-eater when in the divinest state incident to his enjoyment. In that state crowds become an oppression to him, music even too sensual and gross. He naturally seeks solitude and silence as indispensable conditions of those trances or profoundest reveries, which are the crown and consummation of what opium can do for human nature. At that time I often fell into these reveries on taking opium; and more than once it has happened to me on a summer night, when I have been at an open window, in a room from which I could overlook the sea at a mile below me, and could command a view of the great town of L—— at about the same distance, that I have sat from sunset to sunrise, motionless, and without wishing to move."

This description recalls exactly the picture of the confirmed coquero reclining for hours beneath his sheltering tree, absorbed, abstracted, and heedless of all external things. Whether his apathy and phlegm ever approached to that of the coquero, the English Opium-eater does not inform us.

6°. Consumption of Coca-leaf.—We have no accurate data from which to form an estimate of the actual weight of coca-leaf collected and consumed in Bolivia and Peru. Pöppig estimates the money value of the yearly produce to be about 4,500,000 Prussian dollars, which, at 1s. a pound, the price it yields to the grower, would make the annual produce nearly 15,000,000 lb. This approximation is sufficient to show us its importance to the higher regions of South America, in an agricultural and commercial, as well as in a social point of view.

Dr Weddell, again, who has recently travelled in Bolivia, informs us that the province of Yongas, in Bolivia, in which the coca is much cultivated, alone produces 9,600,000 Spanish pounds. The total produce, therefore, is probably much beyond the 15,000,000 deduced from the statement of Pöppig.

The importance of the plant is shown also by another fact mentioned by the same traveller—that the revenue of the state of Bolivia, in 1850, amounted to 10,500,000 francs, of which 900,000, or one-twelfth of the whole, was derived from the tax on coca. Had he told us the amount of the tax per

pound, we should have been able to approximate more nearly to the total produce of the state of Bolivia.

When we consider that eastward from Bolivia and Peru, the culture and use of coca have extended into parts of Brazil, and to the banks of the Amazon, it will not appear exaggerated if we estimate the actual growth and consumption of the dried coca-leaf at 30,000,000 lb. a-year. At 1s. a pound, this is worth £1,500,000 sterling; and at the average produce of 800 lb. an acre, it implies the use of 37,000 acres of good and carefully cultivated land for the growth of this plant. We may estimate also that the chewing of coca is more or less indulged in among about 10,000,000 of the human race.

CHAPTER XXI.

THE NARCOTICS WE INDULGE IN.

THE THORN-APPLES, THE SIBERIAN FUNGUS, AND THE MINOR NARCOTICS.

The red thorn-apple: its use among the Indians of Peru; its remarkable effects; taken by the Indian priests; frenzy induced by it; used in the temples of the Andes and of Greece; Delphic oracles inspired by it; singular coincidence in priestly deceptions.—The common thorn-apple: its use in Europe for criminal purposes; in Russia, for giving headiness to beer; in India, to ardent spirits.—How it is employed by the poisoners of India.—Spectral illusions occasioned by the use of it.—Narcotic qualities of the leaves.—Chemical history of the thorn-apples.—The poisonous daturine and the empyreumatic oil; their joint influence in smoking.—The Siberian fungus: how collected and used; its intoxicating effects; delusions created by it; its active principle escapes in the urine; may be again used repeatedly, and by different persons; Siberian custom.—The common puff-ball; narcotic qualities of its smoke when burning.—Chemistry of the poisonous fungi; they contain amanitine.—Empyreumatic oil of the burning puff-ball.—The minor narcotics: The emetic holly, the narcotic of Florida; how it is used.—The deadly nightshade; its remarkable effects: destruction of a Norwegian army in Scotland.—The common henbane.—The bearded darnel gives headiness to beer, and poisons bread.—Sweet gale; its use for giving bitterness to beer.—Heather-beer of the Picts and Danes.—The rhododendrons, poisonous and narcotic.—The Azalea pontica gives its peculiar qualities to the Euxine or Trebizond honey.—The andromedas and kalmias of North America act as narcotics.—Narcotic effects of sweet odours on some constitutions.

XII. The Thorn-apples.—The history of the thorn-apples as familiar narcotics is no less interesting, and their effects upon the system not less remarkable, than those of any of the sub-

stances I have hitherto described. Two species at least are known to be employed in different parts of the world.

1°. THE RED THORN-APPLE OF PERU (*Datura sanguinea*), fig. 64, is in use among the Indians of the Andes, by some tribes of whom the coca-leaf, already described, is principally consumed. It grows on the less steep slopes of the Andean valleys, and is called by the natives Bovachero, or Yerba de huaca. The fruit of the plant is the part employed, and from it the Indians prepare a strong narcotic drink, which they call Tonga. By the use of this drink they believe that they are brought into communication with the spirits of their forefathers. Von Tschudi had an opportunity of observing an Indian under the influence of this drug, and he thus describes its effects:—"Shortly after having swallowed the beverage, he fell into a heavy stupor. He sat with his eyes vacantly fixed on the ground, his mouth convulsively closed, and his nostrils dilated. In the course of about a quarter of an hour his eyes began to roll, foam issued from his half-opened lips, and his whole body was agitated by frightful convulsions. These violent symptoms having subsided, a profound sleep of several hours succeeded. In the evening, when I saw him again, he was relating to a circle of attentive listeners the particulars of his vision, during which he alleged he had held communication with the spirits of his forefathers. He appeared very weak and exhausted."[1]

Fig. 64.

Datura sanguinea—The Red Thorn-apple. Scale, 1 inch to 9 inches.

In former times, the Indian priests, when they pretended to transport themselves into the presence of their deities, drank

[1] Von Tschudi—Travels in Peru, p. 269.

the juice of this thorn-apple, in order to excite themselves to a state of ecstasy. And although the establishment of Christianity has weaned the Indians from their idolatry, it has not yet banished their old superstitions. They still believe that they can hold communication with the spirits of their ancestors, and that they can obtain from them a clue to the treasures concealed in the *huacas*, or graves: hence the Indian name of the thorn-apple, Huaca-cachu—grave-plant—or Yerba de huaca.

When the decoction is taken very strong, it brings on attacks of furious excitement. The whole plant is narcotic, but it is in the seeds that the greatest virtue resides. These are said by some authors to have been used also by the priests of the Delphic temple in ancient Greece to produce those frenzied ravings which were then called prophecies. Such a practice certainly obtained in the Temple of the Sun at Sogamossa—(LINDLEY). This Sogamossa is near Bogota, in the Andes of New Granada.

It is sufficiently strange to see how similar modes and means of imposition were made use of by the priests of nearly every false religion in ancient times, for the purpose of deluding their credulous countrymen. But it is truly remarkable that among the mountains of Greece, in the palmiest days of that classic country, the same observed effects, of the same wild plant, should have been employed by the priests of Apollo to deceive the intellectual Greeks, as at the same time were daily used by the priests of the sun to deceive the rude and credulous Indians among the far-distant mountains of the Andes. The pretended second-sight, and the other marvels told of the old seers of the Scottish Highlands, may owe their origin to nothing more noble or mysterious than a draught of thorn-apple, night-shade, or belladonna tea. And it is highly probable that the Witches' Drink was flavoured with the thorn-apple, and that the victims who, in all sincerity, came before the magistrates, and declared themselves to have had communication with the Evil One, had, under the influence of this narcotic, seen visions which they could not distinguish from real experience.

2°. THE COMMON THORN-APPLE (*Datura Stramonium*) has been long known even in Europe to possess narcotic pro-

perties. In Germany and France the seeds are said to be frequently made use of for the perpetration of crime.[1] In Russia they are added to beer to make it heady and intoxicating—a practice which formerly prevailed also in China, but has been now long forbidden—(GMELIN). In Upper India, the mountain villagers of Sirinagur, and other provinces, employ the same seeds to add to the intoxicating qualities of their common spirituous liquors. In Lower India, the poisoners, who all belong to the caste of Pasie, or dealers in toddy, make use of the seeds of the datura in plying their odious craft. They go about singly or in gangs, haunting the traveller's resting-places, where they drop half a rupee weight of seeds, pounded or whole, into his food. This produces an intoxication of twenty hours' duration, during which he is robbed, and left either to recover or to sink under the stupefying effects of the narcotic. The seed is gathered at any time, place, or age of the plant, without apparent influence upon its efficacy—(Dr HOOKER).[2] Three East Indian species of *Datura* are said to be in use as narcotics—namely, *D. Melet*, *D. fastuosa*, and *D. alba*.

Dr Sigmond quotes Beverley's History of Jamaica for an account of the effects of *Datura Stramonium*. "This plant," says Beverley, "was gathered very young for a boiled salad by some of the soldiers sent thither (Jamaica) to quell the rebellion of Bacon, and some of them ate plentifully of it; the effect of which was a very pleasant comedy, for they turned natural fools upon it for several days. One would blow up a feather in the air, another would dart straws at it with much fury; another, stark naked, was sitting up in a corner like a monkey, grinning and making mouths at them; a fourth would fondly kiss and paw his companions, and sneer in their faces with a countenance more antic than any in a Dutch doll. In this frantic condition they were confined, lest in their folly they should destroy themselves. A thousand simple tricks they played, and after eleven days returned to themselves again, not remembering anything that had passed."

In this country the seeds are rarely used, except under the direction of a medical man, or when they happen to be swal-

1 Christison On Poisons, p. 841.
2 Himalayan Journals, vol. i. p. 66.

lowed by mistake; and it is singular that when an overdose does happen thus to be taken, especially if it is by a child, the delirium it occasions is often accompanied by spectral illusions more or less wild. A little girl who had taken a drachm and a half of the seeds became furiously delirious in two hours, saw spectral illusions, and so continued during the night, with intervals of lethargic sleep. Next morning she fell fast asleep, and after some hours awoke quite well—(Fowler). The symptoms of this case very closely resemble the reputed effects of the seeds of the red datura on the Indians of New Granada. They remind us of the supposed meetings with their ancestors, which, under the influence of the infusion, the Indians esteem themselves privileged to hold.

The narcotic property is not confined to the seeds, but is probably possessed by the whole plant. Alarming narcotic effects have been produced by applying the leaves to an extensive burn, where, from the removal of the skin, the ingredients of the leaf were capable of being absorbed into the system of the patient. In this country the dried leaves and plant both of *D. Stramonium* and *D. tatula* are frequently smoked by persons affected with certain forms of spasmodic asthma. For this use they are sometimes made up into cigarettes, and sold by the druggists for smoking in the same way as tobacco, though the smoke is generally swallowed.

All the species of thorn-apple, so far as they have hitherto been examined, contain a solid, white, crystalline, poisonous compound or alkaloid, to which the name of daturine has been given. The taste of this substance is at first bitterish, it then becomes acrid, and recalls the taste of tobacco. When taken internally, it strongly dilates the pupil, and in its general action upon the system very much resembles the poisonous principles contained in the well-known common henbane (*Hyoscyamus niger*) and in the deadly nightshade (*Atropa belladonna*). Indeed it is now thought that atropine and daturine are identical. 1000 parts of dried datura seeds contain 4 parts of this active alkaloid. It is to the action of this ingredient that the singular effects produced by the seeds, as above described, are believed to be chiefly due.

But when the thorn-apple, leaf and stem, are smoked, an

empyreumatic oil is produced similar to that which is yielded by tobacco-leaves when burning in the pipe of the smoker.[1] Like that of tobacco, also, this empyreumatic oil is very poisonous. The narcotic, soothing, and spasm-stilling effects of the smoke of the thorn-apple, are partly due to the presence of the vapours of this oil. The poisonous daturine of the stramonium leaf may also rise in vapour and mingle with the smoke, as the poisonous nicotine does with the smoke of burning tobacco (p. 283); while other poisonous vapours may be produced by its combustion. If so, then, as in the case of tobacco, the full effect experienced by smoking the datura is made up of the joint influence of the mixed vapours of the daturine and of the empyreumatic oil which the smoke contains. The presence of these powerfully narcotic and poisonous principles explains why, as experience has proved, the smoking of the thorn-apple is by no means unattended with danger. The custom of swallowing the smoke causes more of the poisonous ingredients to be absorbed into the system than is usually the case in the smoking of tobacco.

XIII. The Siberian or Intoxicating Fungus (*Amanita muscaria*, *Agaricus muscarius*) is to the native of Kamtschatka what opium and hemp are to the eastern Asiatics, coca to the Peruvian, and tobacco to the European and North American races. The natural craving for narcotic indulgences has in Siberia found its gratification in a humble toadstool.

This fungus (fig. 65) has a close resemblance to some of the edible fungi, and is common in birch-woods in some parts of Great Britain. In colour it varies from a bright scarlet to a pale umber; the cap is clothed with scattered warts. It grows very abundantly in some parts of Kamtschatka, and hence its use in that country. It is either collected during the hot months, and hung up to dry in the air, or it is left in the ground to ripen and dry, and is afterwards gathered. The latter are more narcotic than those which are artificially dried.

When steeped in the expressed juice of the native whortleberry (*Vaccinium uliginosum*), or used with the infusion of *Epilobium angustifolium*, this fungus imparts to these liquids the intoxicating properties of strong wine. Eaten fresh in

[1] See the chapter on Tobacco, p. 282.

soups and sauces, it exhibits a less powerful intoxicating quality. But the most common way of using it is to roll it up like a bolus, and to swallow it whole without chewing. If chewed, it is said to disorder the stomach.

Fig. 65.

Agaricus muscarius—Siberian or Intoxicating Fungus.

One large or two small fungi are a common dose to produce a pleasant intoxication for a whole day. If water be drunk after it, the narcotic action is increased. The desired effect comes on in the course of an hour or two after the dose is taken. Cheerfulness is first produced, then the face becomes flushed, giddiness and drunkenness follow in the same way as from wine or spirits, involuntary words and actions succeed, and sometimes the final effect is an entire loss of consciousness. In some it provokes to remarkable activity, and stimulates to bodily exertion. It is said that the Ostiaks of Siberia take the fungus to fit them to commit premeditated assassination. It goads to suicide or brutal exhibitions of passion. Langsdorff relates that a man intoxicated with it was able to carry a sack weighing 120 lb. a distance of 15 versts. In too large doses it induces violent spasms. Upon some individuals it produces effects which are very ludicrous. A talkative person cannot keep silence or secrets. One fond of music is perpetually singing; and if a person under its influence wishes to step over a straw or small stick, he takes a stride or a jump sufficient to clear the trunk of a tree.

The haschisch produces similar erroneous impressions as to size and distance as the one last mentioned. And it is singular that the erroneous perceptions to which these drugs gave rise temporarily—and in the case of haschisch, with a half consciousness of their deceptive character—exist permanently in many lunatics. The reader may also have met with descriptions of old women who were proved to be witches by their being unable to step over a straw!

But the most singular effect of the amanita is the property it imparts to the fluid excretions. It has been known from time immemorial to the inhabitants of Siberia that the fungus gives to the urine an intoxicating quality. This continues for a considerable time after taking it, so that a man who is moderately intoxicated the one day, and has slept himself sober by the next morning, will, by drinking—as is the custom—a tea-cup of his own urine, become more completely intoxicated than before. It is not uncommon, therefore, for confirmed drunkards in that country to preserve their urine as a precious liquor in case of a scarcity of the fungus. This intoxicating property of the fluid is capable of being propagated, so to speak; for every one who partakes of it is similarly affected. Dr Langsdorff says, that if a second person takes the urine of the first, a third that of the second, and so on, intoxication may be propagated through five individuals. Thus, with a very few amanitæ, a party of drunkards may keep up their debauch for a week.

We have already seen that morphia, the active principle of opium, passes through the body into the milk and other liquid excretions. The same is the case also with the active principles of cinchona-bark, of hemlock, of belladonna, aconite, &c. The Siberian fungus is said to contain two peculiar constituents—one a base or alkaloid called *amanitine*, the other an acid, *muscaric acid*. It is probable that the base is the active intoxicating constituent, the acid being probably formed from it.

It has long been observed that poisonous fungi in general, when eaten, produce narcotic among their other effects. It has also been popularly known in this country that the smoke of the burning puff-ball, a fungus in itself often wholesome and eatable, has the property of stupefying bees, and it has frequently been used for that purpose when a hive was to be robbed. But it has recently been tried upon higher orders of animals, and similar effects have been found to be produced upon them also. When the fumes of the burning fungus are slowly inhaled, all the ordinary symptoms of intoxication gradually appear. These are followed first by drowsiness, and then by perfect insensibility to pain, like that which follows the use of chloroform; and if the inhalation be continued, this is succeeded by convulsions, occasionally by vom-

iting, and after some time by death. While recovering from its action, an animal is sometimes perfectly conscious, while it is still insensible to pain.[1]

The chemistry of this tribe of plants is still very obscure. Two active principles, *muscarine* and *amanitine*, however, have been recognised in the fly agaric and in one or two other fungi possessed of poisonous properties. When distilled with water, they yield a volatile acrid principle which has been little examined. It may be to the conjoined influence of the volatile acrid substance, and the two alkaloids just named, upon the system, that the singular effects of the Siberian fungus are to be ascribed.

The usually harmless puff-ball has not yet been shown to contain any narcotic ingredient resembling the amanitine of the poisonous species; but it and several other species are not always equally innocuous—varying conditions of soil, maturity, and climate, influencing the composition and activity of the fungi to a great extent. The narcotic effects produced by the smoke of the puff-ball when burning, must at present be ascribed to the empyreumatic oil, which, like tobacco and the thorn-apples, it yields when burned. This mingles with the smoke, and along with the smoke is drawn into the lungs and there absorbed.

XIV. The Minor Narcotics. — Besides the narcotics already mentioned, which may be regarded as national indulgences, and are used by large bodies of men, there are several which possess so much of a local or historical interest, as to make them not unworthy of a brief consideration. I class these together under the name of Minor Narcotics.

1°. The Emetic Holly (*Ilex vomitoria*) is the narcotic of the Indians of Florida. An infusion or decoction of the leaves is drunk before the opening of their councils, and on other important occasions. That their heads may be clear when grave questions are about to be discussed, they are said to fast three whole days, drinking meanwhile the infusion of this plant. This infusion is sometimes spoken of as the black drink, probably from its colour.

In moderate doses it acts upon the kidneys and increases the perspiration. Taken more largely, it moves the bowels

[1] Medical Times, June 11, 1853; and Chemist, July 1853.

and causes vomiting. Used in the proper manner, it also induces a state of excitement and frenzy; so that among the Seminoles it serves the same purposes as opium does in the East.

The chemical history of this plant is quite unknown. As a holly (*Ilex*), however, it is botanically related to the plant which yields the Paraguay tea.[1] It probably contains an active principle, therefore, which has an analogy to the theine of the tea-leaf.

2°. The Deadly Nightshade.—The black berries of the deadly nightshade or dwale (*Atropa belladonna*), by their beautiful brightness, sometimes tempt the young to eat them by mistake. They are powerfully narcotic, and among their earliest symptoms induce the appearance of the most besotted drunkenness. The dried leaves, or an infusion of the leaves, acts in a similar manner. Even a small dose causes an extravagant delirium, which is usually of an agreeable kind. This is sometimes accompanied by excessive and uncontrollable laughter, sometimes by incessant talking, but occasionally by a complete loss of voice. The state of mind sometimes resembles somnambulism, as in the case of a tailor who for fifteen hours was speechless and insensible to external objects, and yet went through all the operations of his trade with great vivacity, and moved his lips as if in conversation—(Christison).

This narcotic is never now used among us except as a medicine. It possesses an historical interest, however, from the circumstance, related on the authority of Buchanan the historian, "That the destruction of the Danish army, commanded by Sweno, king of Norway, when he invaded Scotland, was owing to the intoxicating qualities of the berries of this plant, which the Scots mixed with the drink they were obliged to furnish to the invaders. For while the Danish soldiers lay under its soporific influence the Scotch fell upon them, and destroyed so many, that there were scarcely sufficient left to carry the king on board of the only ship that returned to Norway."[2]

3°. Common Henbane.—The roots of black henbane (*Hyoscyamus niger*) are strongly narcotic and inebriating. Three

[1] See "The Beverages we Infuse."

[2] Morehouse—On Intoxicating Liquors, p. 104.

grains of the dried watery extract of this root are about equal to one of opium, but it is not so certain in its effects. I am not aware that it has ever been used as a narcotic indulgence.

4°. The Bearded Darnel.—Of the home-grown narcotics, natives of our island, the bearded darnel (*Lolium temulentum*), fig. 66, commonly called sturdy or ryle, creeps occasionally into our fermented liquors and our bread. This grass grows in many places as an abundant weed in the corn-fields of some of our more slovenly farmers. When ripe, it is cut down and thrashed with the corn among which it grows; and when the grain is afterwards imperfectly cleaned, these seeds remain among it. They have been long considered to possess narcotic and singularly intoxicating properties. When malted along with barley, which, when the grain is ill cleaned, sometimes unintentionally happens, they impart their intoxicating quality to the beer, and render it unusually and even dangerously heady. When ground up with wheat and made into bread, they produce a similar effect, especially if the bread be eaten hot. Many instances are on record in which effects of this kind, sometimes amusing and sometimes alarming, have been produced by the unintentional consumption of darneled bread or beer.

Fig. 66.

Lolium temulentum—Bearded Darnel or Ryle.
Scale, 1 inch to 1 foot.
Seeds, natural size.

A case occurred on Christmas-day (1853) at Roscrea, in Ireland, where several families, containing not less than thirty persons, were poisoned by eating darnel-flour in their whole-meal bread. They were attacked by giddiness, staggering, violent tremors similar to those experienced in the *delirium tremens* produced by intoxicating liquors, impaired vision, coldness of the skin and extremities, partial paralysis, and in some cases vomiting. By the use of emetics and stimulants all recovered, though greatly prostrated in strength.

The narcotic principle in these seeds has not yet been discovered. It is even doubtful whether the narcotic effects of

darnel are due to some natural constituent of this fruit or grain, or to an active alkaloid produced in the grain by the attacks of a fungus allied to that causing ergot of rye. When distilled with water they yield a light and a heavy volatile oil; but that the narcotic virtue resides in these oils, has not yet been shown. No volatile alkali, like the nicotine of tobacco (p. 283), has been detected in the water and oils which distil over.

5°. SWEET GALE.—Though now, I believe, out of use in this country, the sweet gale (*Myrica Gale*) is another native narcotic, of which the qualities appear to have been familiar to the ancient inhabitants of our islands. All the Northern nations are said to have used this plant in former times to give bitterness and apparent strength to their fermented liquors. In Sweden this practice still prevails; and as far back as 1440, King Christopher confirmed an *old* law, which inflicted a fine upon those who collected this plant before the proper season, or from another person's land.[1]

A tradition prevails in Ireland that the Danes knew how to make beer out of heather; and Boethius has preserved an early Scotch tradition of a similar kind. "In the deserts and moors of Scotland," he says, "there grows an herb named heather, very nutritive to beasts, birds, and especially to bees. In the month of June it produces a flower of purple hue as sweet as honey. Of this flower the Picts made a delicious and wholesome liquor. The manner of making it has perished with their extermination, as they never showed the craft of making it except to their own blood."[2] It is just possible that the grain of truth contained in this tradition may be, that the Picts *flavoured* their barley-worts with twigs of flowering heather; or that, like other Northern nations, they used the narcotic gale, which grows among the heather, to give a bitter flavour and a more intoxicating quality to the liquor they made from them.

6°. THE RHODODENDRONS form a well-known group of plants, in which much narcotic virtue resides. The flowers of the

[1] Beckwith's History of Inventions (Bohn's edition), vol. ii. p. 385.

[2] A more precise tradition, current in Teviotdale, has been preserved in Leyden's Remains, p. 320, and in Mr Christmas's very curious book, The Cradle of the Twin Giants (vol. ii. p. 198), to which I am indebted for the above extract from Boethius.

Rhododendron arboreum are eaten as a narcotic by the hill-people of India. The rusty-coloured leaves of the *R. campanulatum* are used as snuff by the natives of India, and the brown dust which adheres to the petioles of the kalmias and rhododendrons is used for a similar purpose in the United States of North America—(DECANDOLLE). *R. chrysanthemum*, a Siberian bush, is one of the most active of narcotics.

The *Azalea pontica* (fig. 67), a kindred shrub, which grows abundantly on the borders of the Black Sea, and hangs out its tempting flowers in the season of honey-making, is said to be the source of the narcotic quality for which the Trebizond honey is famous. The effects of the Euxine honey, according to Pallas, resemble those produced by the bearded darnel, and occur where no true rhododendrons grow. The natives, he adds, are well aware of the poisonous qualities of this azalea. Goats, which browse on its leaves before the pastures become green, feel its influence, and both cattle and sheep are sometimes killed by it. The extraordinary effects which the honey, extracted from the flowers of this azalea, produced upon the soldiers of Xenophon,[1] bear ample testimony to their narcotic qualities.

Fig. 67.

Azalea pontica—The Armenian Azalea. Scale for plant in flower, with the leaves unexpanded, 1 inch to 5 feet.—Scale for leaves and cluster of flowers, 1 inch to 3 inches.

I might notice many other plants which, though not employed as indulgences, have yet been frequently observed in common life to exhibit narcotic effects. Thus, among heath-plants, the *Andromeda polifolia*, a small shrub found wild in the bogs of northern Europe and America, is an acrid narcotic, and proves fatal to sheep. Similar properties have been observed in the United States in the *Andromeda mariana*, which is there called kill-lamb, or stagger-

[1] See "The Sweets we Extract."

bush, because it is supposed to be poisonous to lambs and calves, producing a disease called the staggers.

In the same country the leaves of the *Kalmia latifolia* are poisonous to many animals, and are reputed to be narcotic, but their action is feeble. Bigelow states that the flesh of pheasants which have fed on the young shoots is poisonous to man; and cases of severe illness are on record that have been ascribed to this cause alone. This property reminds us of those active ingredients of opium and the Siberian fungus which can pass unchanged through the milk and other liquid excretions of persons who consume them.

About New York and in Long Island the *Kalmia angustifolia* is believed to kill sheep, and is known by the names of sheep-laurel, sheep-poison, lamb-laurel, and lamb-kill. The flowers of the kalmia exude a sweet honey-like juice, which is said when swallowed to bring on a mental intoxication, both formidable in its symptoms and long in duration—(Torrey). In this it appears closely to resemble the Armenian azalea.

Finally, I may remark that, according to Dr Bird, the odour of vanilla intoxicates the labourer who gathers it. Even the perfumes of the rose, the pink, and other common sweet-smelling flowers, act on some persons as narcotic poisons—(Orfila).[1] And the vapours arising from large quantities of saffron are said to produce similar effects—headache, apoplexy, and sometimes death. So much does the constitution of the individual exalt and increase the physiological action of substances which, to the mass of mankind, are not only harmless. but really sources of refined pleasure and enjoyment.

[1] That camphor is capable of doing so in a high degree, is shown by what has recently taken place in Canada West. The 'Toronto Colonist' says: "We are informed that no less than eight persons have been admitted into the lunatic asylum in a state of insanity, occasioned by consuming quantities of camphor to prevent cholera. Some of them carried it about in their pockets, and kept from time to time eating small quantities of it. Others took it dissolved in brandy. In all cases where it was taken in any quantity, it produced insanity."

CHAPTER XXII.

THE NARCOTICS WE INDULGE IN.

GENERAL CONSIDERATIONS.

Extended use of narcotic indulgences.—Numbers of men among whom they are consumed.—The use of them to be restrained chiefly by moral means.—Their agricultural and commercial importance.—Total annual production and value.—Their wonderful properties, and interest to the physiologist.—Analogy between diseased states of mind, natural and artificial.—Do all our feelings arise from physical causes?—Special properties of the different narcotics.—Defective state of our knowledge.—National influence of narcotics.—They react upon the constitution and character.—Coincidences in Asiatic and American customs.—Ancient connection between the continents.—General summary.

I CANNOT dismiss the subject of the narcotics of common life, without drawing the attention of my readers to a few of the more interesting considerations which the facts above enumerated suggest to us.

1°. THEIR EXTENDED USE.—And the first reflection which occurs, as we cast a backward glance over the whole subject, is the almost universal use of narcotic indulgences. Siberia has its fungus; Turkey, India, and China, their opium; Persia, India, and Turkey, with all Africa from Morocco to the Cape of Good Hope, and even the Indians of Brazil, have their hemp and haschisch; India, China, and the Eastern Archipelago, their betel-nut and betel-pepper; the Polynesian islands their daily ava; Peru and Bolivia their long-used coca; New Granada and the Himalayas their red and common thorn-apples; Asia and America, and all the world, we

may say, their tobacco; the Florida Indians their emetic holly; Northern Europe and America their ledums and sweet gale; the Englishman and German their hop; and the Frenchman and Spaniard their lettuce. In Murcia whole families may be seen to go into the gardens, and, sitting on the ground, dine on a profusion of raw lettuce. No nation so ancient but has had its narcotic soother from the most distant times; none so remote and isolated but has found within its own borders a pain-allayer and narcotic care-dispeller of native growth; none so savage which instinct has not led to seek for, and successfully to employ, this form of physiological indulgence. The craving for such indulgence, and the habit of gratifying it, are little less universal than the desire for and the practice of consuming the necessary materials of our common food.

Thus it may be estimated that the several narcotics are used—

Tobacco,	among	800	millions	of men.
Opium,	,,	400	,,	,,
Hemp,	,,	200 to 300	,,	,,
Betel,	,,	100	,,	,,
Coca,	,,	10	,,	,,

It should be recollected that two narcotics, as tobacco and opium, are *both* in use by the same people in many instances. A tendency which is so evidently a part of our general human nature, is not to be suppressed or extinguished by any form of mere physical, fiscal, or statutory restraint. It may sometimes be discouraged or repressed by such means, but even this lesser result is not always attainable. This was proved by the failure of the Spaniards, in their attempts to check the consumption of coca in Peru —of kings and priests to prohibit the spread of smoking in Europe and Western Asia—and more recently by the similar failure of the imperial crusade against the use of opium in China. An empire may be overthrown by inconsiderate statutory intermeddling with the natural instincts, the old habits, or the growing customs of a people, while the instincts and habits themselves are only strengthened and confirmed.

While he laments, therefore, the excesses to which some are led in the use of narcotic substances, the enlightened

philanthropist will look to moral rather than to physical or fiscal means as most likely to repress them. The minds of the people who use them must be enlightened. They must be taught to understand what will promote in the greatest degree both their bodily health and their permanent mental comfort. And what will operate more than all, they must be trained up to self-control and self-restraint, and to the habit of reining in their natural desires for this or that form of gratification. This, unhappily, mere intellectual culture will never do.

It is, indeed, not less melancholy than it is remarkable, that some of the most striking known instances—of the abuse of opium, for example—have occurred among men of great mental powers, and of more than ordinary intellectual attainments. The reader of the preceding pages will recollect the total paralysis of the bodily and mental energies which befell our great Coleridge while he was a slave to opium; and how the English Opium-Eater, as well as many others, found mere intellectual power unable to contend with the excited instinctive cravings of their bodily constitutions, when by long indulgence they had become diseased. Examples like these ought to impress upon every one a Christian sense of his own weakness, and incline him voluntarily to turn aside from the temptations which such men were unable to resist.[1]

2°. Their Agricultural and Commercial Importance.—Then in regard to these narcotic substances, it may be questioned whether many more people are employed in raising the common necessaries of life, than in cultivating and preparing these apparently unnecessary indulgences. Certainly no other crops, except corn, and perhaps cotton, represent more commercial capital, employ more shipping and other means of transport, are the subject of a more extended and unfailing traffic, and the source of greater commercial wealth. The correctness of this may be judged of by the following estimates of the annual produce and value of a few of the narcotics I have mentioned:—

[1] It is comparatively easy to avoid acquiring habits, but it is very difficult to overcome such as are already formed. It was stated some years ago at a temperance meeting in London, that of 600,000 persons in the United States who had taken the pledge, 450,000 had broken it!

	Produce per acre.	Total produce in lb.	Acres employed.	Value per lb.	Total value in pounds sterling.
Tobacco,	800 lb.	4,520,000,000	5,650,000	2d.	£37,667,000
Opium,	20 „	25,000,000	1,250,000	20s.	25,000,000
Hops, .	660 „	323,000,000	490,000	1s.	16,150,000
Coca, .	800 „	30,000,000	37,000	1s.	1,500,000
		4,898,000,000	7,427,000		£80,317,000

Besides these, there are consumed in the East 500,000,000 pounds of betel, and 20,000,000 pounds of catechu and gambir extract.

Of course, all these estimates are to a great extent conjectural, but they are sufficiently near the truth to show how important an influence the narcotic appetite exercises upon the rural labours and commercial intercourse of mankind.

Its influence on domestic economy becomes equally apparent when we consider how large a proportion of the weekly earnings is often among ourselves expended in gratifying this appetite. But in India, where, on an average, not more than sixpence a-head is yearly spent by the whole population in the purchase of clothing,[1] narcotic indulgences form the second great necessary of common life.

3°. Their wonderful action upon the system is not less worthy of attention. The haschisch, besides the more usual intoxicating effect by which it makes the patient, like the infatuated lover, see

"Helen's beauty in a brow of Egypt,"

brings on that remarkable, rare, and inexplicable condition of the living body, which is distinguished by the name of catalepsy. The limbs of the patient may be moved at will by the bystander; but in opposition to the law of gravity, and apparently without an effort on the part of the patient, they remain for an indefinite period in any position in which they may be placed. The thorn-apple calls up spectral illusions before the deceived eye, and enables the forlorn and downtrodden Indian to hold refreshing converse with the spirits of

[1] Bombay Gazette.

his rich and powerful ancestors. The Siberian fungus gives insensibility to pain, while consciousness still remains; and, in common with the haschisch, it creates the singular delusion that a straw is too formidable an obstacle to be stepped over. The common puff-ball deprives the patient of speech, motion, and sensibility to pain, while he remains alive to all that passes around him. It thus realises, and proves to be possible, that nightmare of our dreams, in which we imagine ourselves stretched on the funeral bier, sensible to the weeping of real, and the secret satisfaction of pretended friends; aware of the last screw being fixed in the coffin, and the last sod clapped down above us in the grave-yard, and are yet unable to move a lip for our own deliverance! And then how melancholy the idiotic laughter produced by the deadly nightshade—so like that which, in rare and mournful cases, is seen on the old and withered features of one who, in the vigour of his manhood, charmed the world by the brilliancy of his genius, or astonished it by the majesty of his intellectual powers! How singular, in fine, that influence of *Cocculus indicus*, which leaves the mind clear and strong after the limbs have become feeble and the gait tottering, as if the whole man were deadly drunk!

In all these effects the physiologist finds matter of most attractive, most interesting, most useful, and yet most profound and mysterious study. By what kind of action upon the system does the active ingredient of hemp produce the diseased condition we call catalepsy; or that of the thorn-apple, the condition in which men see visions and dream dreams; or that of the fungus, the fearful state of the most fearful nightmares; or that of the nightshade, the melancholy drivelling of the long-strained and worn-out intellectual faculties? How interesting such questions, yet how impossible, in the present state of our knowledge, to answer them completely!

And yet towards the understanding of these remarkable phases of the human mind chemistry has already brought us far on our way. There are many modes of proving that oxidation within the body is reduced during the action of narcotics. The carbonic acid gas expired is less; the constituents of the urine are reduced; the temperature is lowered; chemistry has put into our hands distinct chemical substances, by

which any one of these states can be produced temporarily and at will. Is it by the agency of similar substances, formed naturally in the system, that these diseased states of mind are naturally produced? If so, can we artificially, and by chemical means, counteract these, so as either to retain the mind in a sound condition, or to restore it to its natural health?

Can we produce, for example, virtual insanity—imaginary happiness, imaginary misery, or the most truth-like delusions —by introducing into the stomach, and thence into the blood which is passing through the hair-like blood-vessels of the brain, a quantity of a foreign body too minute to be recognised by ordinary chemical processes; and may not real natural insanity, in any of its forms, be caused by the natural production within the system itself of minute quantities of analogous substances possessing similar virtues? And, if so produced, will our future chemistry teach us to remove the mental disease, by preventing the production of the cause, or by constantly neutralising its effects?

And these are not merely ends to be aimed at. Even now they appear to be not beyond the pale of hope. For what are so like to each other as the natural and artificial states of mental derangement, and how much light do they throw upon each other? A monomaniac, in apparently perfect bodily health, takes the strangest fancies into his brain, and talks of and reasons upon them as if they were real. A person labouring under delirium sees sights which are invisible to others, and speaks of them to his attendant as real and present. The second-sighted seer, in his gifted moments, receives strange warnings from shadowy ghosts, and with full faith believes in and reveals them. A strong man, under the influence of haschisch, or the Siberian fungus, sees a huge tree in a tiny straw, and persists in his inability to step over it, as if the tree were really there. A child swallows common thorn-apple seeds, and forthwith spectral illusions dance before it, which the child regards as real. A decoction of a similar plant calls up to the presence of the Indian of Peru the spirits of his ancestors; he converses with them; and when the effects of the drug have disappeared, he relates these imaginary conversations to his neighbours, believing them to be real—and, what is stranger still, they are listened to with an equal faith

in their reality. An excited, nervously susceptible, or epileptic female sees lights streaming from human graves, and Will-o'-the-wisps dancing around the poles of a magnet, or issuing in flickering mistiness from the finger-tops of an operator; she believes and describes them as real, and, like the credulous Indians, hundreds around her believe the "odylic" moonshine to be real too. But are the things seen in any one of these cases more true and real than they are in all the rest? Are they not all delusions alike — mere mockeries, which deceive the diseased or drug-affected senses? And if so nearly allied in nature, may they not be so also in cause and in cure? At all events, what interesting chemico-physiological experiments are suggested by these striking analogies!

Some physiologists, reasoning from analogy, go still farther. They ascribe not only these rarer states of mind, but those also which are much more frequent and common, to the direct physiological action of material substances. M. Moreau, for example, guided by his personal experience of the action of the resin of hemp on his own mind, throws out the conjecture "that every feeling of joy and gladness, even when the cause of it is exclusively moral—that those enjoyments which are least connected with material objects, the most spiritual, the most ideal—may be nothing else but sensations purely physical developed in the interior of the system, in the same way as those which are produced by means of the haschisch." In so far as relates to our internal consciousness, at least, he adds, "that there is no distinction to be made between these two orders of sensations, in spite of the diversity of causes to which they are due." This conjecture is eminently suggestive of experimental research, but it goes deeper into the connection between mind and matter than any positive knowledge we possess enables us as yet safely to penetrate.

4°. THE SPECIAL PROPERTIES by which they are severally distinguished are also remarkable features of the narcotics I have described. Thus, while tobacco soothes, and, according to some, sets the mind to sleep, opium and hemp stimulate and exalt the mental faculties, giving the feeling and sense of increased intellectual power. In the case of opium, the activity of mind thus produced resembles the activity of the mind in sleep. It seems as if, all the bodily organs being at rest, the thoughts and images floated over or through the qui-

escent brain without fatiguing or wasting it, as cloud and sunshine flit over a fair landscape without stirring or physically changing it. With hemp it is otherwise. It occasions hunger along with the mental activity. Prolonged thought in the waking man makes the head smoke, as it were. Like physical exertion, it exhausts the body, and brings on a hunger which can only be stayed by ordinary food. And so the mental activity occasioned by hemp resembles more that of the waking than of the sleeping man. This agrees with another observed difference between the two. Opium lessens the susceptibility to external impressions, while haschisch increases and quickens it in a high degree. The one shuts up the mind, as it were, within itself, while the other throws it open to the most lively influence of every bodily sense. It is also in agreement with all these differences, that the action of opium is interrupted and lessened by disturbance and bodily motion, while that of hemp is diminished by stillness and repose. In this latter quality hemp agrees with ardent spirits.

Coca and opium, again, agree in sustaining the strength, in certain circumstances, in a marvellous manner; yet they differ in two important qualities. The former never induces sleep as opium does, and even when taken in great excess, it moves the bowels, while opium usually makes them torpid and costive. Betel rouses from the effects of opium, as tea does from that of ardent spirits. The Siberian fungus opens and shows the heart as good wine is said to do. Secrets drop out spontaneously under its influence, since either the will or the ability to retain them has for the time gone to sleep.

Such specialities are curious and interesting in themselves; but they are so also in showing that the several narcotic substances act upon the system, and disturb the mind in different ways. They strengthen the probability, therefore, that by the use of special chemical substances, we may be able, hereafter, to control the similarly differing mental affections by which natural diseases are so often accompanied.

5°. How defective our Knowledge is.—Yet though, from what we do know, we may venture to express such hopes as these, it must have struck the reader of the preceding chapters how very defective our knowledge is, both of the chemical nature and of the physiological action of the narcotics in

which we indulge. The field of study which they present is indeed captivating and extensive; but hitherto the materials and opportunities for cultivating it have presented themselves rarely, at intervals, and to few individuals. The growing sense of the importance of chemical physiology to the art of medicine, however, promises by-and-by to make the value of a higher acquaintance with chemistry more manifest to medical men, and thus to lead a greater number of that profession to qualify themselves for chemico-physiological investigations. As this desirable change takes place, we may expect to see many gaps in our present knowledge gradually filling up. But the chemical study of the constituents of narcotics will obviously never suffice alone to explain their action on the human system. We must ascertain, by direct experiment, on man, and on the lower animals, the chemical changes which they bring about in the functions and alterations of the body. We must bring the microscope to our aid, and we must give due consideration to the changes caused by ferments. These latter play an important part in health and disease. The unorganised ferments, like pepsine and ptyaline, help to digest our food; organised ferments, minute living creatures, are the poisons of our blood in many acute diseases.

6°. National Influence of Narcotics.—We have seen that almost every part of the world grows and consumes its own peculiar narcotic. The use of each of these in the country which produces it seems natural enough. It is consumed, as the national species or variety of grain is, because it is most easily and plentifully obtained. But when different narcotics are equally accessible, why is one selected rather than another? England, for example, drinks much hopped beer, while Scotland and Ireland drink comparatively little. It is, no doubt, owing to some peculiarity in the national character and constitution that the narcotic hop, and probably also tobacco, are used more largely in the south than in the north of our island—that the German and Swede smoke more than the Frenchman—that opium and haschisch, so loved in the East, have made such slow progress in our European affections. And so the different forms in which the same substance is used are probably, in part at least, constitutional. France, the north of Scotland, Iceland, and Northern Scandinavia, are great consumers of snuff; England, Germany (high and low),

Southern Scandinavia, and Russia, prefer to burn their tobacco, and inhale its smoke. Snuff is much used also by the African races who live between the Red Sea and the Upper Nile, while the Mograbins are great chewers, and the Turks and Arabs as constant smokers—(WERNE). It may be said that differences such as these are mere matters of taste; but national taste, though sometimes the child of habit, is more frequently the offspring of constitution and bodily temperament.

But does the use of the peculiar narcotic not again react upon the constitution, and gradually change the disposition and temperament? It probably does. The soothers and exciters we indulge in to excess are seen gradually to affect the constitution, and sensibly to modify the temper and constitution of individuals. Let the use of these become general, and similar changes will in time affect the whole people. We cannot tell how far such constitutional alterations may proceed. But it is a problem of interest to the legislator, not less than to the physiologist and psychologist, to ascertain how far and in what direction such changes may go—how much of the actual tastes, habits, and character of existing nations has been created by the prolonged consumption and prevailing forms of the narcotics in daily use—how far tastes and habits have been modified by the changes in these forms which have been adopted within historic times—and what influence their continued use is likely to exercise on the final fortunes of this or that people. The fate of nations has frequently been decided by the slow operation of long-acting causes, unthought of and unestimated by the historian, which, while the name and local home of the people remained the same, had gradually changed their constitution, their character, and their capabilities.

7°. ASIATIC AND AMERICAN CUSTOMS.—In connection with this subject, it is also very striking that so many close coincidences should exist between Asiatic and American customs. Such are the assumed ancient use of tobacco in China as well as in Central America—the use of hemp by the natives of Brazil as well as by those of India and the East—the practice of chewing lime or plant-ashes with the coca in Peru, and with the betel in India and China—the use of the red thorn-apple by the hill Indians of the Andes, and of the common thorn-

apple by the hill people on the slopes of the Himalayas. All these coincidences can scarcely be the result of chance; they are evidences rather of ancient intercourse between Asia and America—possibly even of ancient family relationship between their early inhabitants.

We are accustomed to trace analogies among nations by means of alphabets, names of things, forms of speech, modes of writing, religious rites, &c., and from these to infer a family connection or a community of origin. But old habits and peculiar customs of common life, clung to often not only with the fondness of a natural instinct, but with a reverence inspired by high national antiquity—these are not less important evidences of ancient intercourse. They are also more persistent. They may survive after power, civilisation, language, alphabets, writings, and even old religions, have disappeared. The chewing of coca in Peru has outlived all these. The common-life customs and the bodily features of the people have alone survived.

Philological travellers describe, as the most ancient race among the Mexican mountains, a tribe of Indians speaking a monosyllabic language which bears considerable resemblance to the Chinese. The similarity of customs above described is equally close and striking. And the most cautious ethnologist will scarcely refuse to consider the two kinds of evidence as materially aiding each other, and giving strength to the conclusion to which they both point—that a remote family connection exists between the Indian inhabitants of America and the most ancient populations of Eastern Asia.

8°. General Summary.—From all that we know on the subject of the narcotics, we may, I think, extract these general propositions:—

First, That there exists a universal craving in the whole human race for indulgences of a narcotic kind. This is founded in the nature of man.

Secondly, That this craving assumes in every country a form which is more or less special to that country. It is modified most by climate, less by race, and least, though still very sensibly, by opportunity.

Thirdly, That among every people the form of craving special to the whole undergoes subsidiary modifications among individuals. These are determined by individual constitution

first, and next by opportunity. Hence different professions, in consequence of acquired habits and states of body, show the craving in differently modified forms. And hence, also, the different classes of society, because of their unlike means and opportunities, exhibit similar differences.

Fourthly, That differences in physiological action, which are sometimes very slight, separate—

a. The more dreaded from the less dreaded narcotics—opium and hemp from tobacco and the hop.

b. The narcotics from the fermented liquors—opium from alcohol.

c. The milder from the fiercer alcoholic drinks—the beers and wines from the brandies.

d. The mildest fermented drinks from the beverages we infuse—the beers from the teas and coffees.

All these indulgences shade into each other, often by almost imperceptible degrees, and our constitutions, in favourable circumstances, insensibly adapt themselves to them all. How much, therefore, ought we to be on our guard against their insidious attractions!

Fifthly, That one general good effect of all or most of these soothers is, that they remove a disturbing nervous influence by which some of the usual functions of the healthy body are liable to be deranged.

Lastly, I may remark that, with the enticing descriptions before him, which the history of these narcotics presents, we cannot wonder that man, whose constant search on earth is after happiness, and who, too often disappointed here, hopes and longs, and strives to fit himself for happiness hereafter—we cannot wonder that he should at times be caught by the tinselly glare of this corporeal felicity, and should yield himself to habits which, though exquisitely delightful at first, lead him finally both to torture of body and to misery of mind;—that, debilitated by the excesses to which it provokes, he should sink more and more under the influence of a mere drug, and become at last a slave to its tempting seductions. We are indeed feeble creatures, and small in bodily strength, when a grain of haschisch can conquer, or a few drops of laudanum lay us prostrate; but how much weaker in mind, when, knowing the evils they lead us to, we are unable to resist the fascinating temptations of these insidious drugs!

CHAPTER XXIII.

THE POISONS WE SELECT.

The consumption of white arsenic.—Action of arsenic upon the system.—Practice of using it in Styria.—Its effects in improving the complexion and removing breathlessness.—Quantity taken.—Length of time it may be used with impunity.—Illness produced by discontinuing it.—Its effects upon horses.—Its chemico-physiological action in producing these effects.—Ancient love-philtres and charms.—Incredible things formerly believed.—The eating of clay.—Practice in Guinea, in the West Indies, in Java, in the Himalayas.—Use of bread-meal and mountain-meal in Sweden, Finland, and North Germany.—The Otomacs in South America—Humboldt's account.—Does clay support life?—Eaten by the Indians of Bolivia and Peru.—Its physiological action.—Our ignorance still great.

I SHOULD omit from this outline of the chemistry of common life some of the most remarkable features it presents, were I not to add to the preceding chapters on narcotic indulgences a brief notice of two other forms of indulgence not less wonderful and extraordinary. These are, the habitual consumption of arsenic, and the practice of eating clay.

I. THE CONSUMPTION OF WHITE ARSENIC.—Arsenic, as we commonly call it—the white arsenic of the shops and the arsenious oxide of the chemist—is well known as a violent poison. Swallowed in large doses, it is what medical writers call an irritant poison. It forms the really poisonous ingredient in a potion still prepared with magic rites in Ceylon, and to which a large lizard is supposed to contribute its venom—(EMERSON TENNENT). In very minute doses it is known to professional men as a tonic and alterative, and is sometimes administered

with a view to these effects. It is remarkable, also, for exercising a peculiar influence upon the skin, and is therefore occasionally employed in cutaneous diseases. Arsenic, however, is never, I believe, used as a household medicine by the people.

In some parts of Lower Austria, however, in Styria, and especially in the hilly country towards Hungary, there prevails among the common people an extraordinary custom of eating arsenic. During the smelting of lead, copper, and other ores, white arsenic flies off in fumes, and condenses in the solid form in the long chimneys which are usually attached to the smelting furnaces. From these chimneys, in the mining regions, the arsenic is obtained, and is sold to the people by itinerant pedlars and herbalists. It is known by the name of *Hidri*;[1] and the practice of using it is of considerable antiquity. By many it is swallowed daily throughout a long life, and the custom is even handed down hereditarily from father to son.

Arsenic is thus consumed chiefly for two purposes—*First*, To give plumpness to the figure, cleanness and softness to the skin, and beauty and freshness to the complexion. *Secondly*, To improve the breathing and give longness of wind, so that steep and continuous heights may be climbed without difficulty and exhaustion of breath. Both these results are described as following almost invariably from the prolonged use of arsenic either by man or by animals.

For the former purpose young peasants, both male and female, have recourse to it, with the view of adding to their charms in the eyes of each other; and it is singular to see how wonderfully well they attain their object, for those young persons who adopt the practice are generally remarkable for clear and blooming complexions, for full rounded figures, and for a healthy appearance. Dr Von Tschudi gives the following case as having occurred in his own medical practice: "A healthy but pale and thin milkmaid, residing in the parish of H——, had a lover whom she wished to attach to her by a more agreeable exterior; she therefore had recourse to the well-known beautifier, and took arsenic several times a-week. The desired effect was not long in showing itself; for in a few months she became stout, rosy-cheeked, and all

[1] A corruption of *Hutter-rauch*, smelt-house smoke.

that her lover could desire. In order, however, to increase the effect, she incautiously increased the doses of arsenic, and fell a victim to her vanity. She died poisoned, a very painful death." The number of such fatal cases, especially among young persons, is described as by no means inconsiderable.

For the second purpose—that of rendering the breathing easier when going uphill—a small fragment of arsenic is put into the mouth, and allowed to dissolve, which it does very slowly. The effect is described as astonishing. Heights are easily and rapidly ascended, which could not otherwise be surmounted without great difficulty of breathing.

The quantity of arsenic taken by those who are beginning the practice varies with the age, sex, and constitution, but it never exceeds half a grain. This dose is taken two or three times a-week, in the morning fasting, till the patient becomes accustomed to it. The dose is then cautiously increased as the quantity previously taken diminishes in its effect. "The peasant R——," says Dr Von Tschudi, "a hale man of sixty, who enjoys capital health at present, takes for every dose a piece about two grains in weight. For the last forty years he has continued the habit, which he inherited from his father, and which he will transmit to his children."

No symptoms of illness or of chronic poisoning are observable in any of these arsenic-eaters, when the dose is carefully adapted to the constitution and habit of body of the person using it. But if from want of material, or any other cause, the arsenic be left off for a time, symptoms of disease occur which resemble those of slight arsenical poisoning. Especially a great feeling of discomfort arises, great indifference to everything around, anxiety about their own persons, deranged digestion, loss of appetite, feeling of overloading in the stomach, increased flow of saliva, burning from the stomach up to the throat, spasms in the throat, pains in the bowels, constipation, and especially oppression in the breathing. From these symptoms there is only one speedy mode of relief, namely, an immediate return to arsenic-eating.

This custom never amounts to a passion like that of opium-eating in the East, betel-chewing in India, or coca-chewing among the Peruvians. It is not, like opium or hemp, a source of intense pleasure, the craving for which cannot be resisted; but, the habit once acquired, the fear of pain com-

pels its continuance. The use of arsenic has become a necessity of life.

Upon animals the effects are similar to those which are produced upon man. It fattens and plumps out the horse, gives it a bright and glossy skin, and an appearance of high health and condition. Hence this use of arsenic is very common in Vienna, especially among gentlemen's grooms and coachmen. They either sprinkle a pinch of it among the oats, or they tie a piece as big as a pea in linen, and fasten it to the bit when the bridle is put into the horse's mouth. There it is gradually dissolved by the saliva, and swallowed. The sleek, round, glossy appearance of many of the first-rate coach-horses, and especially the foaming at the mouth, which is so much admired, is owing to the arsenic they get. In mountainous districts also, where horses have to drag heavy burdens up steep places, the drivers often put a dose of arsenic into the last portion of food they give them. This practice may be continued for years, with horses as with men, without the least injury; but if a horse which is used to it comes into the possession of one who does not give arsenic, it loses flesh and spirits, and its strength sensibly diminishes. In this state the most nutritious food is unable to restore the animal to its former appearance; but a few pinches of arsenic speedily bring it round again.[1]

Though very different in its nature from the narcotic substances described in the preceding chapters, yet the effects which result from the use of arsenic resemble some of those which are produced by the use of narcotics. Thus arsenic resembles coca in making the food appear to go farther, or to have more effect in feeding or fattening the body; and, like coca, it gives the remarkable power of climbing hills without breathlessness. Farther, it resembles both coca and opium, and especially the latter, in creating a diseased and uncomfortable state of body, when the practice of eating it is interrupted, and in thus becoming, through long use, a necessity of life.

The chemico-physiological action of arsenic in producing these curious effects has not as yet been experimentally investigated. The peculiar influence exercised by arsenic

[1] Medecinische Wochenschrift of Vienna, October 11, 1851, quoted in the British Journal of Homœopathy. The facts, I believe, are undisputed.

upon the skin is the cause of the improved appearance in the complexion of the human subject, and in the outer coat of the horse; but the physiological nature of this influence, and how arsenic comes to exercise it, we cannot even conjecture.

Among other ways in which it acts chemically upon the system, experiment will probably show that it lessens the natural waste of the body, and especially that it diminishes the quantity of carbonic acid discharged from the lungs in a given time. The consequence of this action upon the lungs will be,—*first*, that less oxygen will require to be inhaled, and hence a greater ease in breathing under all circumstances, but which will be especially perceived in climbing hills; *secondly*, that the fat of the food which would otherwise be used up in supplying carbonic acid to be given off by the lungs, will be deposited instead in the cellular tissue beneath the skin, and thus will feed, plump out, and render fat and fleshy the animal which eats it.

Still, how arsenic produces or can produce such a lessening of the carbonic acid formed within the body, and discharged by the lungs, is quite inexplicable; it is another of the chemico-physiological mysteries of which common life, both animal and vegetable, is so full. And to lessen the production of carbonic acid is to lower the temperature and reduce the power of doing work possessed by the body.

The perusal of the above facts regarding arsenic—taken in connection with what has been previously stated as to the effects of the resin of hemp—recalls to our mind the dreamy recollections of what we have been accustomed to consider as the fabulous fancies of easy and credulous times. Love philtres, charms, and potions start up again as real things beneath the light of advancing science. From the influence of hemp and arsenic no heart seems secure—by their assistance no affection unattainable. The wise woman, whom the charmless female of the East consults, administers to the desired one a philtre of haschisch, which deceives his imagination—cheats him into the belief that charms exist, and attractive beauty, where there are none, and defrauds him, as it were, of a love which, with the truth before him, he would never have yielded. She acts directly upon his brain with her hempen potion, leaving the unlovely object he is to admire really as unlovely as before.

But the Styrian peasant-girl, stirred by an unconsciously growing attachment—confiding scarcely to herself her secret feelings, and taking counsel of her inherited wisdom only—really adds, by the use of hidri, to the natural graces of her filling and rounding form, paints with brighter hues her blushing cheeks and tempting lips, and imparts a new and winning lustre to her sparkling eye. Every one sees and admires the reality of her growing beauty: the young men sound her praises, and become suppliants for her favour. She triumphs over the affections of all, and compels the chosen one to her feet.

Thus even cruel arsenic, so often the minister of crime and the parent of sorrow, bears a blessed jewel in its forehead, and, as a love-awakener, becomes at times the harbinger of happiness, the soother of ardent longings, the bestower of contentment and peace!

It is probable that the use of these and many other love-potions has been known to the initiated from very early times—now given to the female to enchance her real charms—now administered to the lords of the creation, to add imaginary beauties to the unattractive. And out of this use must often have sprung fatal results,—to the female, as is now sometimes the case in Styria, from the incautious use of the poisonous arsenic; to the male, as happens daily in the East from the maddening effects of the fiery hemp. They must also have given birth to many hidden crimes which only romance now collects and preserves—the ignorance of the learned having long ago pronounced them unworthy of belief.[1]

[1] The many real follies which the history of love-potions contains, in a great measure justify such incredulity. Such, for example, are the absurdities mentioned in the following passage: "To be brief,—to as great effect does the virgin parchment serve, as doth the amorous potion or love-drink, of which, as the saying is, Lucretius the poet died; and Caligula the emperor became with such another to be enraged, and, in a sort, distracted, and out of his wits; his wife Cæsonia having given him such a kind of drink, who, for that cause, was also slain by the soldiers that had before killed her husband, as Josephus reporteth. And more than so, this seemeth to be that Hippomanes, which is apt to stir and procure love, no less than the true Hippomanes plucked from the forehead of a horse colt, whereof Virgil, Propertius, and other poets speak much; or that Hippomanes which, as Theocritus reporteth, was planted amongst the Arcadians; or that fish called Remora, which, as Aristotle saith, was good for love, and for happy success in suits of law; or

II. The Eating of Clay.—Among the extraordinary passions for eating uncommon things is to be reckoned that which some tribes of people exhibit for eating earth or clay. Though not so directly or immediately poisonous as arsenic, the swallowing of clay, with our ordinary European constitutions and habits, could scarcely be otherwise than injurious to the bodily health; but in Western Africa the negroes of Guinea have been long known to eat a yellowish earth, there called *caouac*, the flavour or taste of which is very agreeable to them, and which is said to cause them no inconvenience. Some addict themselves so excessively to the use of it, that it becomes to them a kind of necessity of their lives—as arsenic does to the Styrian peasant, or opium to the Theriaki—and no punishment is sufficient to restrain them from the practice of consuming it.

When the Guinea negroes used in former times to be carried as slaves to the West India Islands, they were observed to continue the custom of eating clay; but the *caouac* of the American islands, or the substance which the poor negroes attempted in their new homes to substitute for the African earth, was found to injure the health of the slaves who ate it. The practice, therefore, was long ago forbidden, and has probably now died out in our West India colonies. In Martinique, a species of red earth or yellowish tufa was still secretly sold in the markets in 1751; but the use of it has probably ceased in the French colonies also. Whether the custom still exists in Cuba and Brazil, where slavery is not yet entirely extinguished, we do not know.

In Eastern Asia a similar practice prevails in various places. In the island of Java, between Sourabaya and Samarang, Labillardière saw small square reddish cakes of earth sold in the villages for the purpose of being eaten. These have been found by Ehrenberg to consist for the most part of the remains of microscopic animals and plants, which had lived and been deposited in fresh water. In Runjeet valley,

the bird called Sippe, spoken of by the same Aristotle; or the lizard, bruised and infused in wine, according as Theocritus prescribeth; or the hair which is found in the end of a wolf's tail; or else the bone of a frog or toad, which hath been cast into a nest of ants, by whom the flesh thereof hath been gnawed away, as Pliny affirmeth."—The Cradle of the Twin Giants, Science and History, by Henry Christmas, vol. ii. p. 261.

in the Sikkim Himalaya, a red clay occurs, which the natives chew as a cure for the goitre—(HOOKER[1]). The chemical nature of this Indian clay has not been examined.

In Northern Europe, especially in the remote northern parts of Sweden, a kind of earth known by the name of bread-meal is consumed in hundreds of cart-loads, it is said, every year. In Finland a similar earth is commonly mixed with the bread. In both these cases the earth employed consists for the most part of the empty shells of minute infusorial animalcules, in which there cannot exist any ordinary nourishment. In North Germany also, on various occasions, where famine or necessity urged it—as in long-protracted sieges of fortified places—a similar substance, under the name of mountain-meal, has been used as a means of staying hunger.

In tropical America, clay or earth eating is really a serious endemic disease. Children begin the practice quite young. Women lying in bed restless will pull out bits of clay from their hut walls and offer the tempting rubbish to their squalling brats. Dropsy carries off the infantile clay-eaters, and dysentery the mature. So says Dr Galt in his 'Medical Notes of the Upper Amazon.' The eating of clay prevails also among the native Indians on the banks of the Orinoco, and on the mountains of Bolivia and Peru. The most precise and detailed accounts we possess on this subject, in regard to the Indians of the Orinoco, are given by Humboldt. In north latitude 7° 8′, and west longitude 67° 18′, he met with the tribe of the Otomacs, of which he writes as follows:—

"The earth which the Otomacs eat is an unctuous, almost tasteless clay—true potter's earth—which has a yellowish-grey colour, in consequence of a slight admixture of oxide of iron. They select it with great care, and seek it in certain banks on the shores of the Orinoco and Meta. They distinguish the flavour of one kind of earth from that of another, all kinds of clay not being alike acceptable to their palate. They knead this earth into balls, measuring from four to six inches in diameter, and bake them before a slow fire, until the outer surface assumes a reddish colour. Before they are eaten the balls are again moistened. These Indians are mostly wild and uncivilised men, who abhor all tillage. There is a proverb current among the most distant tribes living on

[1] Himalayan Journals, vol. i. p. 145.

the Orinoco, when they wish to speak of anything very unclean—'so dirty that the Otomacs eat it.'

"As long as the waters of the Orinoco and the Meta are low, the people live on fish and turtles. They kill the former with arrows, shooting the fish, as they rise to the surface of the water, with a skill and dexterity that has frequently excited my admiration. At the periodical swelling of the rivers the fishing is stopped, for it is as difficult to fish in deep water as in the deep sea. It is during these intervals, which last from two to three months, that the Otomacs are observed to devour an enormous quantity of earth. We found in their huts considerable stores of clay balls piled up in pyramidal heaps. An Indian will consume from three-quarters of a pound to a pound and a quarter of this food daily, as we were assured by the intelligent monk, Fray Ramon Bueno, a native of Madrid, who had lived among these Indians for a period of twelve years. According to the testimony of the Otomacs themselves, this earth constitutes their main support in the rainy season. They eat, however, in addition, when they can procure them, lizards, several species of small fish, and the roots of a fern. But they are so partial to clay, that even in the dry season, when there is an abundance of fish, they still partake of some of their earth-balls, by way of a *bonne bouche* after their regular meals.

"These people are of a dark copper-brown colour, have unpleasant Tartar-like features, and are stout, but not protuberant. The Franciscan, who had lived amongst them as a missionary, assured us that he had observed no difference in the condition and wellbeing of the Otomacs during the periods in which they lived on this clay. The simple facts are therefore as follows: The Indians undoubtedly consume large quantities of clay without injuring their health; they regard this earth as a nutritious article of food—that is to say, they feel that it will satisfy their hunger for a long time. This property they ascribe exclusively to the clay, and not to the other articles of food which they contrive to procure from time to time in addition to it. If an Otomac be asked what are his winter provisions—the term winter in the torrid parts of South America implying the rainy season—he will point to the heaps of clay in his hut."[1]

[1] Humboldt's Views of Nature, pp. 143-144. Bohn's edition.

Although the mouths of the Orinoco are at no great distance either from the West India Islands or from the colonies of Guiana, this custom of the Otomacs differs so much from that of the Guinea negroes that we can scarcely believe it to have been borrowed by them from any runaway negro slaves. It is more probably of old date, if not indigenous to the country.

This is rendered more likely by the fact that a similar practice prevails towards the south-west, in the hill-country of Bolivia and Peru. In describing the various articles he saw exposed for sale in the provision markets of La Paz, on the eastern Cordillera, Dr Weddell says: "Lastly, the mineral kingdom contributes its share to the Bolivian markets, and it is sufficient to see the important place which this contingent occupies on the stalls of La Paz, to be satisfied that the part it plays is deserving of much attention. The substance I allude to is a species of grey-coloured clay, very unctuous to the touch, and distinguished by the name of *pahsa*. The Indians, who are the only consumers of it, commonly eat it with the bitter potato of the country, *Papa amargas*. They allow it to steep for a certain time in water, so as to make a kind of soup or gruel, and season it with a little salt. It has the taste of ordinary clay.

"At Chiquisaca, the capital of the State, as I was informed, small pots are made of an earth called *chaco*, similar to the pahsa of La Paz. These are eaten like chocolate. I was told of a señorita who had killed herself by an extreme fondness for these little pots, but it appears that the moderate use of pahsa is followed by no bad effects. The chemical examination of these substances shows that they cannot in any way contribute to the nourishment of the body."[1] The chemistry of edible clay has been pretty thoroughly examined. It contains generally a mere trace of organic matter, or of any material that can possibly be really nutritious. Some kinds do not differ at all from ordinary pipe or fire clay, some contain much oxide of iron in addition, and some consist in part of the fine silicious or flinty remains of minute animals. This latter sort, or infusorial earth, is the "berg-mehl," or mountain-meal of North Germany, already alluded to.

The eating of certain varieties of earth or clay may there-

[1] Weddell—Voyage dans le Nord de la Bolivie, p. 161.

fore, be regarded as a very extended practice among the native inhabitants of the tropical regions of the globe. It stays or allays hunger in some unknown way, possibly by diluting the food or spreading it over a larger surface, so that its nutrient materials are more completely digested and utilised. It may be assumed to act somewhat in the same way that the woody fibre in the food of the ox, though itself in great part indigestible, acts as a useful addition to the daily rations of such animals. It enables the body to be sustained in comparative strength, with smaller supplies of ordinary food than are usually necessary, and it can be eaten in moderate quantities even for a length of time without any sensible evil consequences. A fondness even is often acquired for it, so that it comes at last to be regarded and eaten as a dainty. But clay-eating in excess may and does prove fatal to life.

But after all, the effects attributed to clay-eating are so strange that we must confess they cannot yet be wholly explained. That they *are* produced is testified by so many witnesses that we cannot refuse our belief. So contrary do they appear to our experience as to the dependence of animal life and strength on what we rightly call the necessaries of life, that we hesitate to believe what we cannot explain. The more we consider, however, the statements contained in this and the preceding chapters regarding the beverages, the narcotics, and the poisons, the more we shall be satisfied of the imperfect state of our knowledge as to what concerns the maintenance and comfort of our lives. We are especially ignorant still of the conditions as to quantity and forms of food under which man will *refuse to live* in the varied circumstances of climate, habit, and constitution to which he is subject. But this will come under our notice again, in a succeeding chapter, when we consider, "What, How, and Why we Digest."

CHAPTER XXIV.

THE ODOURS WE ENJOY.

VOLATILE OILS AND FRAGRANT RESINS.

Vegetable odours.—The volatile oils; how extracted.—Quantity yielded by plants.—The otto of roses; how collected.—The oils exist in different parts of plants.—Simple and mixed perfumes.—Analogy between odours and sweet sounds.—Odours may resemble and blend with each other.—Extraction of oils by maceration.—Composition of oils of lemons, oranges, &c.—Isomeric oils.—Oils containing oxygen.—Volatile oils of almonds and cinnamon.—Artificial essences.—Oil of spiræa; can be prepared by art.—Manufactured substitutes for oil of bitter almonds.—Nitro-benzol, or Essence de Mirbane, and benzonitril.—The camphors.—Chinese and Borneo camphors.—Balsams of Peru and Tolu.—The odoriferous resins; why they become fragrant on red-hot charcoal; their use as incense.—Vanilla; its fragrance, and analogy to the balsams.—The Tonka bean; coumarin, the odoriferous principle of this bean.—The same principle in vernal grass, melilot, and other plants.—Gives fragrance to hay.

Among the appliances of common life by which the comfort of man in a civilised state is very materially affected, are the odours he enjoys and the smells he dislikes. Upon the origin, nature, mutual relations, and physiological action of these, modern chemistry has thrown much light. I shall therefore, in this place, briefly illustrate their chemical history.

The odours we enjoy are nearly all derived, either directly or indirectly, from the vegetable kingdom. Among scents in common use, musk, civet, and ambergris, are the only ones which owe their origin to animal life; while with pleasant smells of a purely mineral origin we are as yet altogether unacquainted.

I. Vegetable Odours.—The odoriferous substances yielded by plants may be conveniently grouped thus—the volatile oils, such as the oils of lemons and lavender—the camphors, balsams, and sweet-smelling resins—and the volatile ethers, such as those which give their agreeable bouquet to different kinds of wine.

1°. The Volatile Oils.—When the parts of odoriferous plants are distilled with water, an oil passes over along with the steam, and floats on the surface of the water, which condenses in the receiver. This volatile oil usually exhibits in a high degree the peculiar smell, and often also the taste of the plant from which it is extracted. In this way are obtained the oils of roses, lavender, orange-flowers, cinnamon, peppermint, and many others, which in smell and taste remind us at once of the plants from which they have been distilled.

The greater part of the oil usually floats on the surface of the water which distils over along with it. But this water always retains a small portion of the oil in solution, and from this oil it acquires both smell and taste. Thus rose-water, lavender-water, peppermint-water, &c., are simply waters impregnated with a minute quantity of the oil from which they severally derive their names. The water distilled from myrtle-flowers forms that very agreeable perfume known in France by the name of *eau d'ange.*

The quantity of oil yielded by some plants is so small, that the water which distils over along with it retains it all in solution. In such cases the oil is difficult to obtain, and is in consequence very expensive. Roses are among the flowers which yield their oil in such minute quantities, and hence the high price of the pure attar of roses. The rose-gardens at Ghaziepore are fields in which small rose-bushes are planted in rows. In the morning they are red with blossoms, but these are all gathered before mid-day, and their leaves distilled in clay stills, with twice their weight of water. The water which comes over is placed in open vessels, covered with a moist muslin cloth to keep out dust and flies, and exposed all night to the cool air or to artificial cold—as we set out milk to throw up its cream. In the morning, a thin film of oil has collected on the top, which is swept off with a feather, and carefully transferred to a small phial. This is repeated, night

after night, till nearly the whole of the oil is separated from the water. Twenty thousand roses are required to yield a rupee-weight of oil, which sells for £10 sterling—(HOOKER[1]). In the province of Philippopolis it was generally found that 28 cwt. of roses produced 1 lb. of attar. The total yearly yield of this province of European Turkey, before the disastrous war of 1877-78, was 3600 lb. Pure attar of roses is rarely to be met with. That which is sold in the Indian bazaars is adulterated with sandalwood-oil, or diluted with sweet salad-oils. What we obtain in Europe is generally still more diluted, as the price we usually give for it sufficiently shows.

The odoriferous principle is not always diffused uniformly over the whole plant. In some, as in mint and thyme, it resides in the leaves and stem; in others, as in the cinnamon-tree, it is in the bark; in others, as in the sandal and cedar trees, it is in the wood; in others, like the rose, the lily, the violet, and the jasmin,[2] it is in the petals of the flower. In many, like the Tonquin bean, the anise, and the caraway, it is in the seed or fruit; while in some, like ginger, the iris, and the vitivert, it is in the root. It sometimes even happens that distinctly different scents are extracted from different parts of the same plant. Thus the orange-tree, from its leaves, yields a perfume called *petit grain*—from its flowers, another called *neroli*—and from the rind of its fruit the essential oil of oranges, called also essence of Portugal.

The volatile oils and scented waters are used as perfumes for the toilet, to flavour the *bonbons* of the confectioner, or for giving an agreeable relish to the finer dishes of the cook. The oils of roses, lavender, orange-flowers, &c., are sold only for toilet use, and for scenting the preparations of the perfumer; while those of lemons, peppermint, cinnamon, cloves, ginger, &c., are employed almost solely by the confectioner and the cook.

Every pure volatile oil is a definite chemical compound, or

[1] The weight of a rupee is something less than 176 grains. Others say that a thousand roses yield less than 2 grains of oil. Of course, the quantity must vary very much as the scent of the rose is greater or less.

[2] Pure oil of jasmin is almost as rare and dear as pure attar of roses. At the Great Exhibition of 1851, 6 oz. of it were exhibited, the price of which was £9 an oz.

a mixture of two or more such compounds, and is possessed of properties which are fairly constant and peculiar to itself. Among other properties, it possesses an odour, more or less pronounced, by which it can in most cases readily be recognised. Upon this odour, when agreeable, its value and estimation depend; and the quality of the odour determines the purpose, in perfumery or otherwise, for which it is employed. The pure unmixed odours of such single oils are often highly esteemed, and by some persons preferred to all other scents. But in preparing delicate perfumes, it is seldom that a single oil, or the parts of one plant only, are employed for the purpose. The art of the perfumer is shown by the skill with which he combines together the odoriferous principles of various flowers, or mingles together many volatile essences, so as to produce a more grateful scent than any single plant can be made to yield. In this way the *huile de mille fleurs* (oil of a thousand flowers) professes to be made; and the secret recipe for the popular *eau-de-Cologne*—called the perfection of perfumery — depends for its excellence on the same principle.[1]

Odours resemble very much the notes of a musical instrument. Some of them blend easily and naturally with each other, producing a harmonious impression, as it were, on the sense of smell. Heliotrope, vanilla, orange-blossom, and the almond, blend together in this way, and produce different degrees of a nearly similar effect. The same is the case with citron, lemon, vervain, and orange-peel, only these produce a stronger impression, or belong, so to speak, to a higher octave of smells. And again, patchouli, sandal-wood, and vitivert form a third class. It requires, of course, a nice or well-trained sense of smell to perceive this harmony of odours, and to detect the presence of a discordant note. But it is by the skilful admixture, in kind and quantity, of odours producing a similar impression, that the most delicate and unchangeable fragrances are manufactured. When perfumes which strike the same key of the olfactory nerve are mixed together for handkerchief use, no idea of a different scent is awakened as the odour dies away; but when they are not mixed upon this principle, perfumes are often spoken of as becoming *sickly* or *faint*, after they have been a short time in use. A change of

[1] Report of the Juries of the Great Exhibition of 1851, p. 608.

odour of this kind is never perceived in genuine eau-de-Cologne. Oils of orange-flower, lemons, juniper, and rosemary are among those which are mixed and blended together in this perfume. None of them, however, can be separately distinguished by the ordinary sense of smell; but if a few drops of hartshorn be added to an ounce-measure of the water, the lemon smell usually becomes very distinct.

But though, as I have said, each volatile essence is chemically distinct, and possesses properties peculiar to itself, among which the odour is one, yet the delicacy and fragrance of this odour are found to vary considerably with the locality in which the plant that yields it has been grown. Thus, on the shores of the Mediterranean, near Grasse and Nice, the orange-tree and the mignonette bloom to perfection in the low, warm, and sheltered spots; while, in the same region, the violet grows sweeter as we ascend from the lowest land and approach to the foot of the Alps. So lavender and peppermint, grown at Mitcham,[1] in Surrey, yield oils which far excel those of France or other foreign countries, and which bring eight times the price in the market. This effect of soil and climate on the odour of plants resembles that which they exercise in so remarkable a manner on the narcotic constituents of tobacco, opium, and hemp.[2]

The small proportion of volatile oil which many flowers yield by distillation has led to other modes of extracting it for use in perfumery. The flowers are placed between layers of pure fat melted on to glass or metal plates; whole piles of flowers and fat-layers being built up; or alternate layers of flowers and of cotton steeped in a pure fixed oil are similarly arranged, and, after lying for a while, are submitted to pressure. In either way the oil or fat is impregnated more or less strongly with the odour of the flowers, and has acquired a proportionate value. This process is called maceration, *enfleurage*, &c., and fats so perfumed are generally called French pomatums. Spirit of wine extracts the odoriferous principle from these scented fats, and the solutions are employed for the manufacture of perfumed waters. When a plant or some part of it is particularly rich in a volatile oil,

[1] The Mitcham lavender is, however, the produce of *Lavandula vera*, a species distinct from *L. spica*, the plant cultivated chiefly on the Continent.

[2] See "The Narcotics we Indulge in."

then it may be obtained by mere pressure. The oils of lemon and orange-peel are so prepared.

The otto of roses comes chiefly from Constantinople and Smyrna; the oil of lemons from Sicily and Portugal; bergamot in large proportion from Sicily; and anise from Germany and the East Indies. The oil of cloves imported is small in quantity; but the consumption is probably ten times as much, the English wholesale druggists being themselves large distillers of this oil. Caraway is also largely distilled at home; while of oil of lavender probably as much as 6000 lb. are distilled in England, besides much oil of peppermint.

2°. COMPOSITION OF THE VOLATILE OILS.—A large number of the odoriferous essences of plants is composed of the two elementary bodies, carbon and hydrogen only. And what is very remarkable, many of them, which are otherwise very distinct, consist of these two elements united together in the same proportions. Thus. 100 lb. of pure oil of turpentine consist of—

Carbon, ...	88.24 lb.
Hydrogen, ...	11.76 ,,
	100.00 ,,

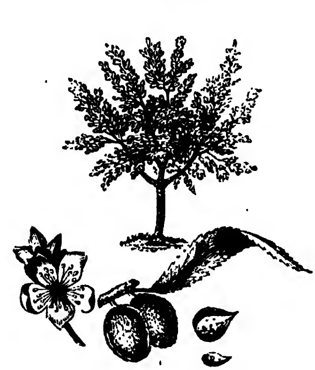
And the oils of lemons, of oranges, of juniper, of rosemary, of copaiba, and many others, though so different in their properties from the oil of turpentine, and from each other, consist of exactly the same proportion ($88\frac{1}{4}$ lb.) of carbon united to the same weight ($11\frac{3}{4}$ lb.) of hydrogen. Substances thus differing in properties, and yet agreeing in composition, are distinguished among chemists by such names as *isomeric*, *metameric*, and *polymeric*—terms signifying that, while the constituent elements are the same in nature and in proportion, their arrangement is not identical, or that they exist in multiple proportions. As an example of the latter case, we may take the oils of caraway and cloves. Caraway-oil contains a hydrocarbon, having the usual composition of the common turpentine—namely, $C_{10}H_{16}$. But clove-oil contains another hydrocarbon, having one-third more carbon and one-third more hydrogen in its molecule—namely, $C_{15}H_{24}$—the same proportions, but larger quantities of its two elements. This is a *polymer*.

Another class of these volatile odoriferous oils contains a

small proportion of oxygen combined with the carbon and hydrogen of which they chiefly consist. To this class belongs the volatile oil which bitter almonds (fig. 68) yield when distilled with water. This fragrant oil is very different from the fixed oil which almonds, both sweet and bitter, yield when submitted to pressure, and is much used by the confectioner and cook.

Of the same kind is the oil of cinnamon, which the young bark of the cinnamon laurel (fig. 69) yields when distilled

Fig. 68.



Amygdalus communis, var. *amara*—The Bitter Almond.
Scale, 1 inch to 20 feet.
Scale for flowers, leaf, fruit, stone, and kernel, 1 inch to 3 inches.

Fig. 69.

Cinnamomum zeylanicum—The Cinnamon Laurel.
Scale, 1 inch to 20 feet.
Scale for leaf, 1 inch to 4 inches.
Fruit, natural size.

with water; and also the oil which is obtained from aniseseed by a similar process. But in this class the proportions of the several constituents are rarely the same in two different oils. Thus the three oils above mentioned consist, in 100 parts, respectively of—

	Oil of Anise.	Oil of Cinnamon.	Oil of Bitter Almonds.
Carbon, . .	81.08	81.82	79.24
Hydrogen, .	8.11	6.06	5.66
Oxygen, . .	10.81	12.12	15.10
	100.00	100.00	100.00

Oil of roses consists of two compounds—one solid and scent-

less, the other liquid and fragrant. The former by oxidation easily passes into the latter. The oils of rose, citronelle, and many others belong to this class, though in many cases a kind of turpentine or hydrocarbon accompanies the oxidised oil, which is their chief and characteristic ingredient. They nearly all differ from one another in composition, the proportions of the three elements varying in each case.

3°. Artificial Essences.—It was long a character of all the volatile oils of the kinds above mentioned, that they could not be formed or imitated by chemical art. The progress of chemistry, however, has recently made us acquainted with several odoriferous essences, somewhat peculiar in kind, which *can* be prepared by artificial processes; and this advance is probably only the forerunner of many similar discoveries by which our power over matter is hereafter to be enlarged.

But as yet a few only of the essential or volatile oils just described can be prepared by artificial means in the laboratory. Plants possess the strange hereditary power of producing the identical chemical compound through long ages, but man has not yet succeeded in making oil of lemons or oil of rose. Still the progress of chemistry has already enabled us to prepare a few fragrant oils, such as those of meadow-sweet, bitter almonds, and winter-green. When the flowers of the meadow-sweet (*Spiræa ulmaria*, fig. 70) are distilled with water, they yield a sweet-smelling substance, known as the *essence of spiræa*, which contains oxygen. This essence resembles in its odour the oil of bitter almonds, and is remarkable for possessing the properties of the substances known to chemists as *aldehydes*.

Fig. 70.

Spiræa ulmaria—The Queen of the Meadows.
Scale, 1 inch to 1 foot.

Common aldehyde passes by oxidation into vinegar, or acetic acid, while the aldehyde of spiræa passes into *salicylic* acid.

Now when water is boiled upon the bark of the willow-tree (*salix*), it extracts from the bark a bitter substance, to which

the name of *salicine* is given, and which possesses many of the fever-dispelling virtues of the well-known quinine. When this bitter substance is heated along with bichromate of potash and sulphuric acid, it is converted into essence of spiræa, or salicylic aldehyde. Thus we have a method of forming this essence without the use of the natural flowers of the spiræa itself. And although this method is too expensive to be adopted on a large scale for the manufacture of the essence for practical purposes, it is a type of a whole series of processes by which one vegetable compound may be made to yield a new, and in some cases more valuable, compound. We can now make oil of bitter almonds, or benzoic aldehyde, and also the fragrant principle of vanilla, by artificial means. And we now know at least two chemical preparations which closely resemble the oil of bitter almonds, and can be cheaply prepared by art.

This oil, as is well known, is highly prized, extensively used, and comparatively costly. The methods by which it is imitated are as follows:—

First, When common coal is distilled in our gas-works, a quantity of tarry matter (coal-tar) comes over along with the gas which is used for lighting our streets. When this tarry matter is again distilled by itself, a thin, very combustible liquid, known as coal-naphtha, is obtained. This coal-naphtha is a mixture of various substances, one of which is a very light colourless liquid, distinguished by the name of *benzol* or *benzene*. When this benzol is carefully mixed with nitric acid (aquafortis), it unites with it and forms a sweet-scented compound (*nitro-benzol*), which in odour and general appearance somewhat nearly resembles oil of bitter almonds. It is known and sold in commerce under the names of *artificial oil of bitter almonds*, and of *Essence de Mirbane*. It differs in composition from the true volatile oil of bitter almonds; but it resembles it in odour, and is a tolerable substitute for it in the scenting of soaps. But it is not a pleasant substitute for the true oil in confections and cookery, for its taste and smell are somewhat coarse, and it is not very wholesome, to say the least. Now the true bitter-almond-oil, when freed from the prussic acid which invariably and necessarily accompanies the crude oil as distilled (for it is formed simultaneously), is destitute of poisonous properties.

The *second* mode of imitating this volatile oil has recourse to substances of a very different origin. The urine of the horse and the cow contains an acid substance which is easily extracted from it in the solid state, and which is known to chemists by the name of *hippuric acid.* When this acid, mixed with sand and chloride of zinc, is heated in a retort over a lamp, it decomposes, giving off carbonic acid gas, while there then distils over a liquid substance, containing 13½ per cent of nitrogen, to which the name of *benzonitril* has been given. The odour of this liquid also is similar to that of the volatile oil of bitter almonds.

The thoughtful reader will rightly appreciate the tendency and social importance of results and researches such as these, with which modern chemical investigations abound. They tend to give a new value to waste materials, by discovering new uses for them, and to cheapen at the same time, and bring within reach of the many, the luxuries and material refinements heretofore confined to the few.

4°. The Camphors, Odorous Crystalline Solids, and Aromatic Balsams and Resins, are all more or less solid, possess a fragrance more or less agreeable, and always contain oxygen as one of their constituents. By combination with oxygen, many of the volatile oils become changed into resins.

The Camphors.—There are several known varieties of camphor. The two most familiar in commerce are the camphor of Japan, called also Dutch camphor, because it is usually brought to Europe by the Dutch—and the China or Formosa camphor. Every part of the camphor-tree (*Camphora officinarum*), fig. 71, is impregnated with the perfume. It is extracted by chopping the branches and boiling them in water; the camphor rises to the surface, and becomes solid when the water is afterwards allowed to cool.

The odour of the camphors is powerful, very characteristic, and to many persons very agreeable. Camphor is used for scenting soaps, tooth-powders, and numerous other preparations for the toilet, for preserving fabrics and animal matters from moth, and for medicine.

What is called Borneo camphor is obtained from reservoirs in the trunk of a different tree, *Dryabalanops aromatica*, which, like the camphor-tree, belongs to the Laurel Order.

Borneo camphor may be oxidised by nitric acid into common camphor; indeed it stands in the same relation to common camphor as alcohol does to aldehyde.

The Balsams are thick, more or less fragrant, fluids, which, like the common turpentines, are obtained by making incisions into the bark of the trees which yield them. The balsam of Peru, and the balsam of Tolu, which are among the best known, are extracted in this way from species of *Myroxylon* which grow in Peru, New Granada, San Salvador, and on the banks of the Magdalena in South America. They consist chiefly of an odoriferous volatile oil, which comes over when they are distilled alone, and of a resin nearly void of smell which remains behind. The balsam of Peru has a powerful but agreeable odour, resembling that of vanilla. The balsam of Tolu is very fragrant, though less powerfully so than that of Peru. The fragrance of both is increased, and somewhat changed, when they are dropped on a red-hot coal. While burning, the inodorous resin decomposes, and gives off an agreeable scent.

Fig. 71.

Camphora officinarum—The Camphor Laurel, or Camphire tree.
Scale, 1 inch to 20 feet.
Scale for flower and leaf, 1 inch to 4 inches.

For their natural odour these balsams are used as an ingredient in various perfumes; they are also employed in medicine. For the additional scent they give off when burned, they are employed as incense, and in preparing the fumigating pastilles which we burn in the chambers of the sick and elsewhere to disguise or overpower unpleasant smells. Both Peru and Tolu balsams contain *cinnamic acid*, a crystalline acid related to oil of cinnamon.

The Odoriferous Resins, such as myrrh and frankincense, have comparatively little natural fragrance. The balsamic

resins, such as storax and benzoin, have more decided odours, and, like the true balsams, recall the sweet smell of vanilla. Like the camphors and balsams, all are used to some extent in preparing articles for the toilet.

But it is for the odours they evolve when burned that they are chiefly used and valued. When thrown in the state of powder upon burning charcoal, myrrh, frankincense, aloes, benzoin, storax, olibanum, and other resins of this kind, emit an agreeable fragrance. Hence they are largely used for burning as incense in the Greek and Romish churches and in pagan temples. When burned in this way, three effects are produced: *first*, the volatile oil is driven off in vapour, and diffuses through the air the scent emitted by the resin in its natural state; *secondly*, white vapours of a volatile fragrant acid, which exists partly ready formed in the resin,[1] ascend and mingle their smell with that of the volatile oil; and, *thirdly*, another volatile aromatic oil is produced by the decomposition of the resin upon the red-hot charcoal. The vapours of this oil also rise and unite with those of the other substances, and thus produce the full effect upon the olfactory nerves for which the most esteemed varieties of incense are valued, and disguise more effectually the offensive effluvia from the dirty clothes and unwashed bodies of the worshippers.

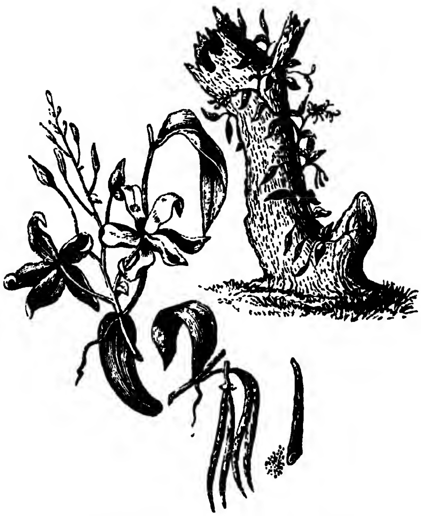
Vanilla.—I have described the balsams as possessing an odour which resembles that of vanilla (fig. 72). This highly-prized perfume resides in the pods of an orchidaceous plant (*Vanilla aromatica* or *planifolia*), long known to the ancient Mexicans for its remarkable fragrance, and probably used by them, as it is now, for flavouring their favourite chocolate. The best vanilla is still brought from Mexico, though less esteemed varieties are produced by species of the plant which grow in other parts of tropical America,[2] and much is now grown in Réunion, Mauritius, Guadaloupe, and Demerara.

[1] From benzoin the fragrant *benzoic* acid is given off—from storax, and the balsams of Peru and Tolu, the *cinnamic* acid. The benzoic acid is white, solid, and crystalline; and, though so different in its properties, is remarkable for possessing the same ultimate chemical composition as the volatile essence of spiræa already described. The cinnamic acid is very like the benzoic, and derives its name from the fragrant oil of cinnamon, which, by combining with oxygen, forms cinnamic acid.

[2] See Map of Vanilla Countries, p. 360.

The fruit of this plant, as shown in the annexed figure, is a long pulpy pod, filled with rounded seeds. When ripe, the pod is said to yield from two to six drops of a liquid which has an exquisite odour, and bears the name of balsam of vanilla. This balsam, however, is never seen in Europe.

Fig. 72.



Vanilla planifolia—The Aromatic Vanilla.
Scale for plant, 1 inch to 6 feet.
Scale for flowers and fruit, 1 inch to 6 inches.

The pods are dried in the sun, and afterwards slightly fermented, for the purpose of developing their odour, as, when fresh, they are said to be without smell. In some places they are afterwards rubbed over with oil, and in this state sent to market.

The odoriferous principle of vanilla is a beautiful colourless crystalline substance called *vanillin*, soluble in alcohol and in boiling water. It melts easily, and turns into vapour slowly at the ordinary temperature. Bottles in which vanilla pods have been kept sometimes become like the pods themselves, encrusted with crystals of vanillin. Vanillin in 100 parts contains—

Carbon,	63.1
Hydrogen,	5.3
Oxygen,	31.6
	100.0

Vanillin has been produced from a substance called coniferin occurring in the sapwood of certain firs. The artificial flavourer not merely resembles but is identical with the natural.

As a perfume, vanilla is highly esteemed. Its principal use, however, is in flavouring chocolate, ices, creams, and other confectionary. Coffee, and even tea, are sometimes also flavoured with it. Physiologically, it acts upon the system as an aromatic stimulant, exhilarating the mental functions, and increasing generally the energy of the animal system. Like some other odours—those of camphor and patchouli, for example—that of vanilla sometimes exhibits narcotic effects upon those who are much exposed to it.

Fig. 73.

Dipterix odorata—The Tonquin Bean tree. Scale, 1 inch to 40 feet. Leaves and raceme of flowers, 1 inch to 4 inches. *a*, Flower; *b*, Kernel or bean; *c*, Pod or fruit. 1 inch to 2 inches.

Five or six hundredweight of vanilla are yearly imported into this country.

Coumarin.—Nearly allied to the fragrant resins is an interesting and widely-diffused natural perfume, to which chemists have given the name of *coumarin*. A fragrant bean, the Tonka or Tonquin bean (fig. 73), the fruit of the *Dipterix odorata* of Guiana, formerly well known in this country, and much employed for perfuming snuff (by a recent regulation not more than 3 per cent of ground Tonquin beans may be added to snuff), contains this substance *coumarin*. Alcohol readily extracts

it from the bean; and by evaporating the alcoholic solution, we obtain the substance in a solid state. It forms white brilliant needles, soluble in hot water and spirit, and possessed of an agreeable aromatic odour. When heated, it melts and rises in vapour; and this vapour, when inhaled, acts powerfully upon the brain. It consists of carbon, hydrogen, and oxygen, in the following proportions:—

Carbon,	74
Hydrogen,	4
Oxygen,	22
	100

But the interesting circumstance in the history of this substance is that, though discovered first in a foreign bean, the produce of a warm climate, it has since been found to exist in, and to impart their well-known agreeable odours to, several of our most common European plants. Among these, the sweet-scented vernal grass (fig. 74), to which we are in the habit of ascribing the fragrance of well-made hay, deserves especial mention. This grass contains coumarin, and imparts to dry hay the odour of this substance.

Fig. 74.

Anthoxanthum odoratum—Sweet-scented vernal grass Scale, 1 inch to 9 inches. Single flower, glume, and seed, natural size.

The following is a list of the sweet-smelling plants in which coumarin, either free or associated with such closely-allied acids as the melilotic and coumaric, has already been found:—

Dipterix odorata, or Tonka bean.
Angræcum fragrans, the Faham tea-plant of Mauritius.
Asperula odorata, the common sweet-woodruff.
Anthoxanthum odoratum, the sweet-scented vernal grass.
Melilotus officinalis, or common melilot.
Melilotus cærulea, the blue or Swiss melilot.
Hierochloe borealis, the northern holy grass.

It is the same odour, therefore, which gives fragrance to the Tonka bean, to the Faham tea of the Mauritius, to our melilot trefoil, and to sweet-smelling hay-fields, in which melilot and vernal grass abound. In Switzerland the blue

melilot is mixed with particular kinds of scented cheese, and the coumarin it contains gives to the cheese of Schabzieger its peculiar well-known odour. Coumarin has been prepared artificially, from the oil of *Spiræa ulmaria* (see p. 418). And several other coumarins having very pleasant odours have been made.

Many sweet-smelling grasses are known, such as *Ataxia horsfieldii*, *Andropogon Iwacancusa*, *Andropogon Schoenanthus* or ginger-grass, &c., &c., in which coumarin probably does not exist. Indeed, the *Andropogon citratus*, *A. muricatus*, and allied species (the *Melissa kuskus* of India), yield distinct and fragrant oils, used as medicines and perfumes in that country. There are other sweet-smelling substances, therefore, without doubt, from which grasses dried for hay, in different countries, may derive an agreeable odour.

It has been thought that hay-fever, to which many sensitive people are liable during hay-time, may be due to the diffusion of coumarin in the air at that season. But the notion is probably incorrect. It is more probable that hay-fever is due to tiny organisms, low forms of living matter, excessively simple in structure and minute in size, which are known to be peculiarly abundant in the pollen of certain grasses. An injection into the nostrils of a weak solution of sulphate of quinine allays the unpleasant symptoms of hay-fever by killing these organisms.

CHAPTER XXV.

THE ODOURS WE ENJOY.

THE VOLATILE ETHERS AND ANIMAL ODOURS.

Wine-ether, how prepared.—Nitric ether and acetic ether.—Wood-spirit and wood-ether.—Potato-spirit, or oil of grain, and potato-ethers.—Oil of winter-green, a natural ether; how prepared artificially.—Sweet-smelling ethers manufactured as perfumes.—Pear-oil, or essence of jargonelle.—Apple-oil.—Grape and cognac oils.—Pine-apple oil.—Hungarian wine-oil, and other artificial fragrances.—Caprylic ethers.—The flavour of whisky.—Propylic ethers.—The bouquet of wines.—Œnanthic ether gives the generic flavour to grape-wines.—Characteristic fragrant principles of different wines.—Use of the sweet-flag in flavouring spirits and beer; its abundance in Norfolk.—Odoriferous substances of animal origin.—Musk; the musk-deer; lasting smell of musk.—Civet.—Effect of dilution upon odoriferous substances.—Use of civet in Africa.—Castoreum and hyraceum.—Ambergris and perfumes prepared from it.—Insect odours.—General reflections.—Extreme diffusiveness of odours.—Delicacy of the organs of smell.—How chemistry increases our comforts, gives rise to new arts, and generally civilises.

II. The Volatile Ethers yielded by plants, like the crystalline principles vanillin and coumarin, have been studied of late by the chemist. His interest in them arises in part from the circumstance that a careful analytical examination of some of those produced in living plants, has given us the key not only to the true chemical composition of these substances themselves, but also to the mode of producing by art an almost endless variety of odoriferous compounds.

1°. Wine-Ethers.—When spirit of wine (alcohol) is mixed with twice its bulk of common oil of vitriol (sulphuric acid)

in a retort, and distilled by the aid of heat, a very light, volatile, and somewhat fragrant liquid passes over, which is known by the name of *ether*, or wine-ether. In chemical language it is the oxide of ethyl, while alcohol is the hydrate.

If into the retort, along with the alcohol and sulphuric acid, a sufficient quantity of nitrate of potash (saltpetre) be introduced before the mixture is distilled, the nitric acid of the saltpetre[1] acts upon the alcohol, forming water, and a *compound ether*—the nitrate of ethyl or nitric ether of the shops—distils over. It is very light, volatile, and not unpleasantly odoriferous. If, instead of saltpetre, acetate of potash be introduced into the retort, acetic acid unites with the ether during the distillation, and acetic ether, another volatile ethereal compound, distils over.

By similar processes many other acids may be made to yield compound ethers, each possessed of a composition and properties peculiar to itself.

2°. Wood-Ethers.—When dry wood is distilled in iron retorts for the manufacture of wood-vinegar, there comes over, along with the tar, water, and vinegar, a quantity of a peculiar alcohol, which is separated and sold under the name of wood-spirit. Methylated spirit is spirit of wine containing 10 per cent of this wood-spirit.

When this wood-spirit is distilled with sulphuric acid, as in the first of the processes above described, a peculiar ether comes over, which is known as wood-spirit ether, or wood-ether. This ether differs from wood-spirit as wine-ether does from wine-spirit (common alcohol), in being an oxide instead of a hydrate. From wood-spirit, compound ethers may be formed nearly in the same way as they are formed from the wine-spirit. These compound ethers have a general resemblance, in properties and composition, to those formed from the wine-spirit; but each of them possesses a peculiar composition and sensible properties, by which it can be distinguished more or less readily from every other compound body.

3°. Potato-Ethers.—When brandy is manufactured from potatoes,[2] there comes over along with it, in the first dis-

[1] Nitric acid, known commonly by the name of aquafortis, unites with potash, and forms *nitrate* of potash, or saltpetre, and water. Acetic acid (vinegar) and potash form *acetate* of potash and water.

[2] See p. 250.

tillation, an oily liquid in which there is found a quantity of a third peculiar spirit or alcohol, known as potato-spirit. It exists also in the crude spirits distilled from grain,[1] and from grape-husks, and gives to these varieties of brandy their disagreeable flavour. By repeated rectifications it is separated from the brandy, and may thus be obtained in a pure state. It is more unpleasant to the taste and smell, and more maddeningly intoxicating, than wine-alcohol; and hence the peculiar, violent, and often poisonous effects produced by ill-rectified grain and other raw spirits.

When this potato-spirit is distilled with oil of vitriol, it also yields a peculiar volatile ethereal liquid—the potato-spirit ether, or briefly the potato-ether; and by processes similar to those already described, compound ethers are readily obtained in which this potato-ether is combined with the nitric, the acetic, and many other acids.

For certain chemical reasons, which it is unnecessary here to state, in chemical language—

> Wine-spirit is ethyl alcohol; wine-ether is ethyl oxide.
> Wood-spirit is methyl alcohol; wood-ether is methyl oxide.
> Potato-spirit is amyl alcohol; potato-ether is amyl oxide.

And the compound ethers they severally form are named after the acid and simple ether they respectively contain. Thus the common nitric ether I have mentioned is *nitrate* of ethyl, common acetic ether the *acetate* of ethyl—and so on.

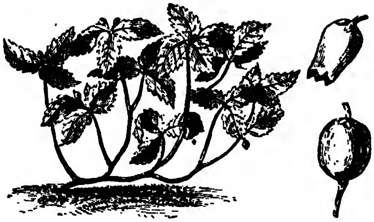
With the aid of this preliminary explanation, the non-chemical reader will readily understand and appreciate what follows on the subject of ethereal perfumes.

4°. Oil of Winter-green.—In the State of New Jersey, in North America, the partridge-berry, tea-berry, or winter-green (*Gaultheria procumbens*) fig. 75, grows abundantly in the woods and drier swamps. It is a dwarf evergreen fragrant heath-plant, and possesses an agreeable aromatic odour resembling that of the sweet birch. It has long been gathered and distilled, like other fragrant plants, for the sake of the volatile oil, which in this way may be extracted from it. This natural essence is largely imported into Europe as a perfume, and is known in commerce by the name of *oil of winter-green.*

[1] Hence it is called also *oil of grain*, and by the Germans *fusel oil.*

About thirty years ago, a French chemist (M. Cahours), in experimenting with this oil, discovered that, unlike the sweet-scented volatile oils usually yielded by plants—those of peppermint, cinnamon, anise, juniper, &c.—this was a compound body belonging to the known family of compound ethers, and, like them, was capable of being decomposed and again recompounded by chemical art. This was the first step in a new direction, and opened up a fresh field of practical inquiry, which, though as yet only partially cultivated, has already yielded most unexpected fruits.

Fig. 75.



Gaultheria procumbens—Winter-green of New Jersey.
Scale, 1 inch to 5 inches.
Flower and fruit, natural size.

I have already spoken (p. 418) of the bitter substance, *salicine*, which by a peculiar process can be made to yield the fragrant essence of spiræa. By another simple process this salicine[1] produces a solid crystalline acid substance, the salicylic acid. Now salicylic acid forms with methyl the basis of wood-ether, a compound ether called methyl salicylate, and this is found to be identical with the oil of winter-green. This compound is produced naturally in the *Gaultheria procumbens*, and in the bark of *Betula lenta*, and the leaves of *Andromeda Laschenaultii;* but the same esteemed perfume, now that we know its nature, we can also make by art. Salicylic acid may also be more cheaply made from carbolic acid, a coal-tar product, than from salicine.

5°. Artificial sweet-smelling Ethers.—Chemical research, however, had meanwhile been discovering in the laboratory other compound ethers, not known to occur in nature, but which were distinguished by smells so sweet as to entitle them to be placed among valuable perfumes. Many of these

[1] Salicine is largely extracted from willow-bark, and is employed in preference to quinine amid the marshes of the Danube, in Turkey, and in the Eastern Archipelago—being less stimulating, and therefore better suited to the constitution and circumstances of the native inhabitants of these parts of the earth.

have a well-established place in the market, and have become articles of extensive and profitable manufacture. Thus, under the name of—

a. Pear-oil, or essence of jargonelle pears, is sold a spirituous solution of acetate of amyl[1] derived from vinegar and potato-spirit. This ether, when pure, has a peculiar fruity smell, but when mixed with six times its bulk of spirit of wine, it acquires the peculiar pleasant odour and flavour of the jargonelle pear! Whether the pear, when ripe, really contains any of this ether, is not known. It is largely manufactured, however, chiefly for the use of the confectioners. Among other purposes, they employ it to flavour pear-drops, which are merely barley-sugar flavoured with an infinitesimal quantity of this ether. If these are not always as pleasant in taste as they might be, it may be due to the excessive quantity of amyl acetate used, or to the presence of the offensive potato-spirit itself.

b. Apple-oil, again, is a compound of the same potato or amylic ether, with an acid known to chemists by the name of the *valerianic*. It is easily prepared, by substituting the *bi-chromate* of potash for the acetate of potash employed in the manufacture of pear-oil. The pure ether becomes the commercial apple-oil, when it is dissolved in five or six times its bulk of alcohol. It has then a most agreeable flavour of apples, and is employed largely by the confectioners.

c. Grape-oil and *cognac-oil* are also formed from amyl or potato-ether and acids. They are used for giving the desired cognac flavour to British-made and other inferior brandies.

It will strike the reader as not unworthy of remark, that the same potato-spirit which, because of its offensive smell and taste, is carefully removed by the rectifier from the ardent spirits he distils, should, under the hands of the chemist, become possessed of the most agreeable and coveted fragrance!

d. Pine-apple oil, again, is common wine-ether combined with butyric acid, and then dissolved in alcohol. It has the pleasant flavour of the pine-apple, and is employed in England to flavour sweetmeats and an acidulated drink or lemonade called pine-apple ale. In Germany it is used to flavour bad rums.

[1] Prepared, as already described, by distilling potato-spirit with oil of vitriol and acetate of potash.

The butyric acid contained in this compound ether is the substance which gives its peculiar disagreeable odour to rancid butter. One mode of preparing the ether is to make butter into a soap, and to distil this soap with alcohol and sulphuric acid.[1]

e. Hungarian wine-oil is wine-ether in combination with a peculiar acid called the œnanthic acid. This compound exists in all grape-wines, and, when extracted, is employed for flavouring an artificial cognac which can scarcely be distinguished from the genuine. For this purpose it has been sold in Breslau, at the price of sixty-nine dollars a pound! It was prepared in Hungary—whence its name—and was distilled from wine-husks. It has been examined by Schwartz, who, besides making out its composition and chemical relations, has also suggested a cheap process by which it may hereafter be abundantly prepared.

f. Other artificial fragrances.—The above are only samples, so to speak, of the almost endless variety of artificial compound ethers, possessed of sweet smells, which are either already manufactured, or are capable of being so, easily and cheaply, for use as perfumes. Essences of quinces and of melons have been prepared.

There are, for example, many other acids which are capable of forming compound ethers possessed of agreeable odours. We know already that the formic and hippuric acids[2] each yield with the wine and wood spirit ethers, agreeable perfumes, the formiates and benzoates of methyl and ethyl; and the number of similar compounds which may be formed with other acids is almost inexhaustible.

Then, besides the three simple ethers prepared from wine, wood, and potato spirits, there are many other simple ethers, not so commonly known as these, each of which, with the same host of acids, yields compounds of a more or less odoriferous character. Thus—

[1] Another mode is, to mix sugar with powdered chalk and a little curd of milk, in water, and set it aside. The curd gradually causes the sugar to change, first into lactic acid, and then into butyric acid, which combines with the lime of the chalk. This butyr*ate* of lime, distilled with alcohol and sulphuric acid, gives the pine-apple oil.

[2] The formic acid is the acid of ants, but it can also be formed artificially. The hippuric acid is extracted from the drainings of stables.

Caprylic ether, or oxide of capryl, yields with acetic acid a compound of a most intense and pleasant smell. The chloride too of capryl has an orange odour. Those ethers which it forms with other acids are still scarcely known, but many of them are remarkable for their aromatic odour. To the drinkers of whisky it may be interesting to know that the peculiar flavour of this liquor is believed to be due to the presence of a compound of this caprylic ether.[1] Again—

Propylic ether, or oxide of propyl, when combined with butyric acid, yields a pure odour of pine-apple superior to that which the same acid gives when combined with wine-ether. And many other sweet smells, still unknown, will no doubt become familiar to us when the compounds of this singular substance are further investigated.[2]

6°. The Bouquet of Wines.—Among the odours we enjoy is to be reckoned the bouquet of our favourite wines. This bouquet is owing mainly to the presence of one or more volatile ethereal oils, similar to those I have above described.

Generally speaking, the peculiar character of a wine is dependent upon at least two volatile compounds possessed of odours more or less distinct. One of these is common to all good grape-wines—the other is characteristic of the kind of wine, sometimes even of the sample we are examining. As in a well-made eau-de-Cologne, so the excellence of a bouquet or the value it imparts to the wine which possesses it, depends very much on the way and degree in which the odours of those several compounds harmonise and flow into each other.

When a vinous liquor of any kind is submitted to distillation, it yields, besides common wine-alcohol, two ethers, one of which is the acetic ether before described, while the other is œnanthic[3] ether. It is the same as the Hungarian

[1] Caprylic ether is prepared from one of the acid substances contained in butter. The peculiar turpentine manufactured in some parts of Germany rom the Scotch fir (*Pinus sylvestris*), very closely approaches the oil of whisky in smell. This, however, is merely a variety of turpentine, and not an ether.

[2] Propylic ether, or oxide of propyl, is prepared from another alcohol, the propylic; and I have called it a singular substance because, while this oxide of propyl yields delightful odours, another compound of the same propyl yields repulsive smells, like those of boiled crabs, herring-brine, and stinking fish.

[3] From οινον, wine; and ανθος, a flower.

wine-oil already described, and consists of common wine-ether united to a peculiar acid, the œnanthic. This ether, when pure, possesses the characteristic odour of grape-wine in a very high degree. It gives what may be called the fundamental or generic flavour to all grape-wines.

But wines contain other odorous substances besides the two ethers just named. Our knowledge of these fragrant materials is at present very imperfect, but we may attribute to them the specific flavours or bouquets of particular sorts of wine. They appear to consist in great measure of compound ethers; such as butyrate of ethyl and analogous compounds.

I need scarcely observe that the practice of flavouring brandies and beers, so as to give them an esteemed bouquet, has been long known and extensively practised. I have already mentioned certain compound ethers—the Hungarian wine-oil, and the pine-apple oil for example — which are employed to give the flavour of cognac or of rum to inferior spirits, and the use of juniper in the manufacture of gin is known to every one. A less familiar flavourer is the sweet flag, the *calamus* of the Song of Solomon (fig. 76). This imparts at once an aromatic taste and an agreeable bouquet or odour to the liquid in which it is infused. It is used by the rectifiers to improve the flavour of gin, and is largely employed to give a peculiar taste and fragrance to certain varieties of beer. It abounds in the rivers of Norfolk, and from this locality the London market used to be principally supplied. As much as £40 has been sometimes obtained for the year's growth of a single acre of the river-side land, on which it naturally grows.

Fig. 76.

Acorus calamus—The Sweet Flag.
Scale, 1 inch to 10 inches.

III. Animal Odours.—Most species of animals emit from their skin an odour peculiar to themselves, by which other

animals, keen of scent, can recognise and trace them. The blood and flesh of animals also possess a peculiar smell, and only long habit prevents us from distinguishing in this way the flesh of the ox, the sheep, and the pig. The parts of animals have rarely so powerful an odour as to cause them on that account to be either rejected or selected for economical purposes. It is different with the secretion of animal bodies. Some of these are offensively disagreeable to the sense of smell, while others are sought after and valued as agreeable perfumes. Among the latter, musk, civet, and ambergris are the most important.

1°. MUSK is a substance which is found secreted in a small bag, attached to the under part of the body of a ruminating animal of the size of a roebuck (fig. 77), which inhabits the mountains of China, Thibet, Tonquin, Tartary, and Siberia. It is obtained only from the male animal. When fresh, it is in the state of a soft, salve-like, reddish-brown mass. It possesses a peculiar, penetrating, long-continuing odour; and a bitter, astringent, aromatic, slightly saline taste. By keeping, it dries, becomes blackish-brown, and assumes the form of little rounded grains, which give a brown streak upon paper, and are easily rubbed to powder. It is one of the most powerful, most penetrating, and most lasting of odoriferous substances. It attaches itself, and gives a durable scent to everything in its neighbourhood. Different qualities of musk are met with in the market, and from its high price it is very liable to adulteration. When pure, it dissolves in water to the extent of three-fourths of the whole.

Fig. 77.

Moschus moschiferus—Musk-deer.

The chemical nature of musk is not thoroughly understood. It contains several less valuable ingredients, the general properties and origin of which are known; but the chemical characters and composition of that ingredient which emits the esteemed odour have not yet been rigorously investigated.

So persistent and apparently indestructible is the odorous principle of musk, that when taken internally, as it frequently is in cases of spasms, it passes through the pores of the skin, and impregnates the perspiration with a strong smell of musk. When kept in capsules of wax, however, or in contact with lime, with milk of sulphur, with sulphide of gold, or with syrup of almonds, musk loses its smell. But in all these cases the smell is restored by moistening it with liquid ammonia (hartshorn).

The flesh of the crocodile and the alligator smells of musk, while the musk-rat derives its name from the smell it emits. The same odour is sometimes emitted by plants. Thus our common beet has a musky smell, and the musk-plant of our gardens possesses it more distinctly. But the *Delphinium glaciale*, a plant which grows on the Himalayas at the height of 17,000 feet, has so strong and disagreeable a smell of musk, that the natives believe the musk-deer, which is found on the mountain-slopes, to derive its smell from eating this plant. Another Delphinium, the *D. brunonianum*, which grows on the western slopes of the Himalayas, has a similar smell of musk, though less disagreeable—(HOOKER). The nature of the musky-smelling substances contained in these plants is not yet known.

About 14,000 ounces of musk are imported into this country every year. From British India about 7000 ounces are annually exported. Each natural bag or sac weighs only about half an ounce, less than half of which consists of musk. It is somewhat remarkable that while this scent is so much esteemed in England and other countries, it is extensively disliked in Italy, and makes many persons ill.

2°. CIVET.—The substance known in commerce by the name of civet, is secreted by two animals of the genus Viverra (*V. zibetha* and *V. civetta*), one of which is a native of Asia, and the other of Africa. It is of a pale-yellow or brownish colour, has usually the consistence of honey, and possesses a somewhat acrid taste. Its smell resembles that of musk. When undiluted, this smell is so powerful as to be offensive to many; but when mixed with a large quantity of fat, or other diluting substance, it becomes agreeably aromatic, fragrant, and delicate.[1] It is used only as a perfume, and chiefly to

[1] It throws some light upon the diversity of taste which prevails in regard

mingle with and improve the odour of less costly scents. Lavender and other scented waters are made more agreeable by a skilful addition of civet, in minute proportions.

Over Northern Africa, between the Red Sea and Abyssinia, the civet-cat, called by the Arabs *kedis*, is highly valued. Numbers of them are kept in wicker cages for the purpose of collecting the civet they secrete. It is used by the women for the purpose of powdering the upper parts of their body, their necks, &c. Its strong odour overpowers the disagreeable effluvium which often escapes from their dusky skins in that arid climate.[1]

Fig. 78.

Viverra civetta—Civet-cat.

The blacks of Angola, too, use the skin of the civet-cat to scent their clothes and bodies. If the clothes of a person touch the grass where one of these animals has been, they acquire a most persistent musky odour. Other species of Viverra are known—all possess the civet odour. In the northern province of Ceylon the glossy genette or civet-cat, *Viverra indica*, abounds. The Tamils confine it in cages, and collect the perfume from the bars.

Castoreum, yielded by the beaver, is a natural secretion, similar in its origin and its properties to musk and civet. Like these substances, it has, when fresh, a powerful penetrating odour, and a bitter acrid taste. The odour, however, is fetid and disagreeable: it is only used in medicine, therefore, and never as a perfume. In 1875 over 3000 lb. were imported.

Hyraceum is a similar substance obtained from the mountain-

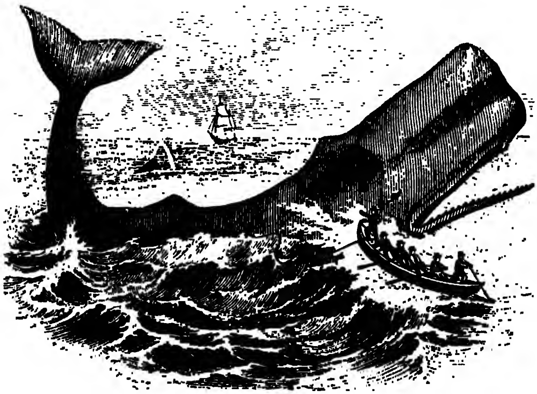
to scents, that the same substance may be agreeable in a diluted, which is offensive in a concentrated state. The volatile oils of neroli, thyme, and patchouli, are in themselves unpleasant; but when diluted with a thousand times their bulk of oil or spirit, their fragrance is delightful. So the odoriferous ethers require to be diluted with six times their weight of alcohol before they can be used as perfumes.

[1] Werne's African Wanderings (Travellers' Library), pp. 187, 260.

badger (*Hyrax capensis*). It resembles castoreum in smell, and is sometimes used medicinally in its stead.

3°. Ambergris is an odoriferous substance which is occasionally found floating on the sea near the Molucca Islands, in other parts of the Indian Ocean, and off the coast of South America. It is a diseased product formed in the intestines of the sperm-whale (*Physeter macrocephalus*), in which it has sometimes been found.

Fig. 79.



Physeter macrocephalus—Sperm-whale.

When fresh, ambergris is solid, greyish, streaked, or marbled, and somewhat soft. It has a strong agreeable odour, resembling that of musk, and a fatty taste. It consists, to the amount of six-sevenths of the whole (85 per cent), of a crystalline substance, soluble in alcohol, called *ambrein*, probably identical with *cholesterin*, from bile and brain. It is not known to what ingredient its value as a perfume is owing. It sometimes fetches £2 an ounce.

Ambergris is rarely employed alone. The essence of ambergris of the perfumer is an alcoholic tincture of the substance, to which the oils of roses, cloves, &c., are added, according to fancy. What is called *tincture of civet* is formed by macerating half an ounce of civet with a quarter of an ounce of ambergris in a quart of rectified spirit. Either of these tinctures, added in minute quantity to lavender-water,

to tooth-powder, hair-powder, toilet-soaps, &c., communicates to them the peculiar odour of ambergris.

In fixity and permanence of scent the animal odours are unrivalled. A handkerchief scented with ambergris retains the odour even after it has been washed; musk and civet are scarcely less permanent. To this property these substances owe their chief use in perfumery. They impart to volatile handkerchief-scents a smell which continues after the less fixed ingredients have disappeared. A favourite mixed perfume of this kind, the *extrait d'ambre* of the Parisian perfumers, is compounded of—

Esprit de rose triple, ...	½ pint.
Extract of ambergris, ...	1 „
Essence of musk, ...	½ „
Extract of vanilla, ...	2 ounces.

When well perfumed with this, a handkerchief, though washed, retains an odour still.

The high price which ambergris, like musk and civet, brings in the market, leads to frequent adulterations, both in this country and in those from which it is imported. The chemistry of this substance is not yet so well understood as to justify us in hoping soon to produce its odoriferous ingredient by artificial processes. Yet the observation, that dried cow-dung smells of ambergris—(REDWOOD)—and that even nightsoil, under certain forms of treatment, assumes a powerful odour of this substance—(HOMBERG)[1]—suggests lines of research, by following which a mode of manufacturing ambergris may hereafter be discovered.

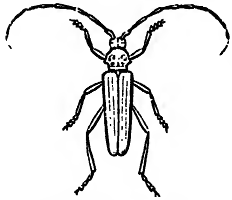
4°. INSECT ODOURS.—Among animal odours of an agreeable kind, those given off by certain insects are deserving of mention. To entomologists, many strong-smelling insects are known, though some of these, of course, are far from being agreeable to our senses.

The *Cerambyx moschata* (fig. 80), a coleopterous insect, derives its specific name from the musky odour it emits. Most of the ants of Europe give off, when crushed, a well-known penetrating odour of formic acid: those of Bahia in South America, which are very troublesome and destructive, give off when squeezed a strong smell of lemons—(WETHERELL). The *Gyrinus natator* of Linnæus has so

[1] Memoirs of the French Academy, 1711.

strong an odour, that, when several of the insects are collected together, they may be scented at a distance of five or six hundred paces—(Roesel). It is to the eating of these insects that Mr Lloyd[1] is inclined to ascribe the remarkable odour emitted by the grayling (*Thymallus vulgaris*), which by different writers has been likened to that of thyme or of honey. Many of the Ichneumonidæ emit an odour, powerful and agreeable, like that of otto of roses.

Fig. 80.



Cerambyx moschata
Half natural size.

I do not multiply examples of this kind, as nothing is yet known as to the chemical nature of the odoriferous substances which insects emit; nor have any of them as yet been employed for purposes of luxury or economy.

Many reflections are suggested by the facts I have brought together in the present chapter. Want of space forbids me to indulge in more than one or two.

First, One circumstance which presses very strongly upon our attention, is the extremely minute state of diffusion in which the odoriferous substances of animal origin still make themselves perceptible to our senses. A fragment of musk not only gives off a strong smell when it is first exposed to the air, but it continues to do so for an almost indefinite period of time. Yet the odour must be caused by particles of matter which are continuously escaping from the musk, so long as it remains exposed to the air. How inconceivably small in weight, how infinitely minute in size, the molecules must be of which this constantly-flowing stream of matter consists!

And to vegetable perfumes the same observations almost equally apply. A single leaf of melilot will for years preserve and manifest its sweet odour, and yet the quantity of coumarin it contains would probably be inappreciable by the most delicate balance. We know in this country how a stalk of mignonette, placed in an open window, will scent the air that enters, through the whole of a long summer's day. But in hot climates, especially during the morning and evening hours, this diffusiveness of perfumes is still more

[1] Scandinavian Adventures, i. 128.

striking. "The odour of the balsam-yielding Humeriades has been perceived at a distance of three miles from the shores of South America—a species of Tetracera sends its perfume as far from the island of Cuba—and the aroma of the Spice Islands is wafted out to sea."[1] Aromatic woods or a drop of mercury preserves cloth from insects, yet lose no appreciable weight.

The quantity of ethereal oil which gives its peculiar aroma to grape-wine has been estimated at one-forty-thousandth only of the bulk of the wine, and that which gives the aroma to roasted coffee, at one-fifty-thousandth of its weight; but ozone is distinctly perceptible to the smell when mixed with 500,000 times its bulk of air.

Secondly, The nicety of the bodily organs by which we perceive these extremely diluted perfumes is equally a subject for admiration. The sense of smell detects and determines the presence of these infinitesimally minute molecules. This is remarkable. But it does much more. It distinguishes between them, pronouncing the impression it derives from one class to be agreeable, and from another class the reverse. It then further pronounces upon the amount and kind of the pleasurable sensation produced by each, and this through a long series of varieties and degrees. How delicate the structure of the organs of smell must be! How surprising that they should continue uninjured and unimpaired, amid so much thoughtless usage, and for so long a series of years!

Thirdly, This history of the odours we enjoy illustrates in a remarkable manner, how, out of the most vile materials, chemistry, by its magical processes, can extract the sweetest and most desirable substances. How wonderful this power, how delightful to possess it, how useful its results! Artificial musk and ambergris! Manufactories of oil of bitter almonds! Essences of spiræa and winter-green prepared in chemical laboratories! Humble wines successfully flavoured to compete with the produce of the most costly vintages! Ethereal fragrances without number, and unknown by name, added to the list of enjoyable odours! Pleasing scents, in cheap abundance, of which the wealthiest in ancient times could form no conception, and which they had no means of obtaining!

[1] Mrs Somerville's Physical Geography, ii. 122.

This history presents, in truth, another striking illustration of the way in which modern chemical research leads to the establishment of new arts and manufactures—to the addition of new and unknown luxuries to those already within our reach—to the cheapening of luxurious comforts to all,—and thus to the refining, and softening, and polishing of the whole community. It displays, also, to the reader the existence of a new field for practical and economic research which is almost boundless, shows how valuable chemistry is in almost every walk of life, and how the studies of the laboratory may be made a source even of money profit in the most unexpected departments of economic pursuit.

CHAPTER XXVI.

THE SMELLS WE DISLIKE.

NATURAL SMELLS.

Difference of opinion as to smells.—Disagreeable mineral smells.—Sulphuretted hydrogen; its properties, and production in nature.—Sulphurous acid given off from volcanoes; its suffocating reputation.—Muriatic acid gas.—Unpleasant vegetable smells.—Garlic and the onion.—Oil of garlic.—Sulphuret of allyl.—Sulphur an ingredient of many fetid smells.—Asafœtida, a concrete juice.—Oil of asafœtida.—Extensive use of vegetable substances containing allyl; they satisfy some natural craving; extensive distribution of them in nature.—Mustard also contains allyl.—The stinking goosefoot.—The peculiar strong-smelling compound contained in this plant exists also in putrid fish; economical use of it in the *cuisine*.—Carrion-plants; the *Saussurea* and the *Stapelias*.—Smells often disagreeable only because of the things or memories associated with them.—Disagreeable animal odours; the goat, the badger, and the skunk.—Effects of minute doses of sulphur and tellurium.—Stenches as weapons of defence.—Insect-smells.—The putrefaction of animal bodies; conditions which promote it; substances given off; their unwholesome character.—Burying-vaults and graveyards.—The droppings of animals; peculiar substances and smells given off by these.

THE smells we dislike are probably quite as numerous as the odours we enjoy. Between the two, however, there is a wide debatable ground, in regard to which the utmost diversity of opinion prevails. What is fragrance to one person is sometimes abomination to another. Plutarch tells us that a Spartan lady paid a visit to Berenice, the wife of Dejotarus; but that one of them smelled so much of sweet ointment, and the other of butter, that neither of them could endure the

other: similar differences of taste still prevail, even among the most cultivated and refined. For although cultivation may very much improve this taste, and though individual constitution modifies in a certain degree the effect which odoriferous substances produce upon the organs of smell, yet early habit determines for the most part the judgments we form as to the agreeable and the disagreeable. The historians of the time thought it worthy of record that Cardinal Olivieri Carafa, who died at Rome in 1511, aged 81, had an invincible repugnance to the smell of a rose.

Still, as there are certain odours which nearly all persons enjoy, so there are certain smells which almost every one dislikes. These are distinctly indicated by the old English word *stinks*. Of these acknowledged bad smells, some are produced naturally, while others are the result of artificial processes. In the present chapter I shall consider only the bad smells which occur in nature. Of these some are of mineral, some of vegetable, and some of animal origin.

I. Mineral Smells.—Of disagreeable mineral smells, the most common are the sulphuretted hydrogen and sulphurous acid. The former gives its disagreeable smell and taste to sulphureous mineral waters, like those of Harrogate; the latter is given off from the mouths of active volcanoes, and from cracks and fumaroles in volcanic countries. Hydrochloric acid is also occasionally discharged by active volcanoes.

1°. *Sulphuretted Hydrogen.*—When common sulphur and iron-filings are melted together in a red-hot crucible, they combine chemically, and form a black *sulphide of iron.* If this black substance be put into a flask or retort along with diluted sulphuric acid (oil of vitriol), a gas is given off, generally without the application of heat. This gas consists of sulphur and hydrogen, and is therefore called sulphuretted hydrogen. This gas may be collected over water in the usual way. It has no colour, but is distinguished by a sulphury taste, and a strong fetid sulphureous smell resembling that of rotten eggs. It is about one-fifth heavier than common air, burns with a blue flame and a smell of sulphur, and is very poisonous when breathed. A single gallon of it, mixed with 1200 of air, will render it poisonous to birds, and one in a hundred will kill a dog. A very small proportion of

it, therefore, mingled with the air we breathe, will render it injurious to human health. Water dissolves two and a half times its bulk of this gas, and acquires at the same time its smell and taste.

This gas is often produced naturally in the interior of the earth, and, rising upwards through the rocks, is absorbed by springs, and gives them the unpleasant smell familiar to us in many mineral waters. It is the sulphuretted hydrogen they contain which causes these waters to blacken when mixed with those of other springs which contain iron.

From marshy and stagnant places also, where vegetable matter is undergoing decay in the presence of water containing gypsum (sulphate of lime), this gas is often given off; and its smell may in most cases be perceived in moist soils, where gypsum lies in contact with decaying roots and leaves. In volcanic countries it frequently issues from the earth in larger quantities. From fissures and openings in the solfataras of Italy, for example, as in that of Pozzuoli, it rushes out, mixed with steam and other gases, and diffuses its fetid odour sometimes to great distances. In such localities the smell of this substance becomes a serious annoyance.

The iron pyrites of our coal-mines, when thrown up in heaps in the open air, undergoes decomposition through the action of the moisture of the atmosphere. One of the results of this decomposition is the evolution of sulphuretted hydrogen gas, sometimes in sufficient quantity to be both offensive and unwholesome to the immediate neighbourhood.

This gas consists, as I have said, of sulphur and hydrogen only, in the proportions, in 100 parts, of—

Hydrogen,	5.9
Sulphur,	94.1
	100.0

So that a comparatively small proportion of hydrogen causes sulphur to assume the gaseous form, and to exhibit the fetid odour and remarkably poisonous properties possessed by this gas.

2°. *Sulphurous Acid Gas.*—When sulphur is kindled in the air, it burns with a pale-blue flame, and is converted into a heavy acid vapour or gas, which is distinguished by a peculiar suffocating smell. This is well known as the smell of

burning sulphur. It is formed by the union of the sulphur with its own weight of the oxygen of the atmosphere, and is called by chemists sulphurous acid gas, or sulphur dioxide. It is two and a fifth times heavier than common air; and when inhaled, it first provokes cough, and if the inhalation be continued, causes suffocation.

This gas is given off from the mouths of active volcanoes, from vents and fissures in the earth in volcanic countries, and from the solfataras which often exist where volcanic action is going on. It is almost as much disliked for its smell as is sulphuretted hydrogen, and it is even more suffocating when breathed.

The universal dislike of this gas is indicated by the place so generally assigned to it, in figurative descriptions, of a future place of torment. Thus, in the Book of Revelation, we have "the lake which burneth with fire and brimstone, which is the second death;" and in Milton's description, it is a place

> "Where peace
> And rest can never dwell; hope never comes,
> That comes to all; but torture without end
> Still urges, and a fiery deluge, fed
> With *ever-burning sulphur*, unconsumed."

3°. *Hydrochloric Acid.*—When oil of vitriol (sulphuric acid) is poured upon common salt, white vapours are given off, which provoke cough, are very suffocating, and affect the sense of smell in an exceedingly unpleasant manner. These are vapours of hydrochloric acid or *spirit of salt.* They are absorbed by water with great rapidity; and when conducted by a bent tube into a bottle of water till the latter is saturated, they form the strongly corrosive acid liquid usually known by the name of spirit of salt.

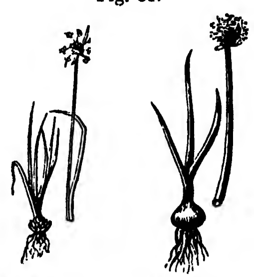
Vapours of this gas are sometimes given off from the mouths of active volcanoes; but they rarely prove an annoyance to the neighbouring population. But they are abundantly produced in the glazing of stoneware by means of salt, and constitute a serious nuisance in some pottery districts. But the two most common and best-known evil smells of mineral origin are those of the sulphuretted hydrogen and the sulphurous acid gases. Of these, the former is by far the more widely diffused and the more frequently observed, and

is productive of the more general annoyance. The sulphurous acid gas is naturally produced only in the neighbourhood of volcanoes, or where sulphur, by some natural means is made to burn in the air.

II. VEGETABLE SMELLS.—Of the smells we dislike, a much greater number are of vegetable than of mineral origin; and of these, some are given off by living plants, which produce and contain essential oils to which their smells are owing. Among these, I advert more particularly to the garlic tribe, the asafœtida plant, and the stinking goosefoot, both because they all emit smells which, in a concentrated form, are generally considered very unpleasant, and because the chemistry of the evil-smelling substances they contain is at present better understood than that of any other known substances of the same kind and origin.

1°. *Garlic and the Onion.*—A familiar plant in many of our moist woods and shady meadows is the common ramps, or ramsons (*Allium ursinum*). When in flower, this plant diffuses its disagreeable garlic odour through the air, and imparts its unpleasant flavour to the milk of cows eating it. When distilled with water in a retort, a heavy volatile oil passes over and collects beneath the water, which condenses in the receiver. The common onion, the chive, the shallot, the leek, the common garlic, and other species of this strong-smelling tribe of plants, yield the same oil when distilled with water.

Fig. 81.



Allium sativum—The Cultivated Garlic. | *Allium Cepa*—The Common Onion.
Scale, 1 inch to 1 foot.

This oil is of a brownish-yellow colour, is heavier than water, and possesses the peculiar smell of the class of plants which yields it, but in a highly pungent and concentrated form, though it is often, in part at least, formed during distillation, and does not exist ready-formed in all the plants which may be made to yield it. It is their strong-smelling principle or ingredient. The strength of its odour may be

judged of from the fact that, powerfully smelling as garlic is, from thirty to forty pounds of it are required to yield one ounce of the oil.

We have seen that a large class of the volatile perfumes which are extracted from plants—such as the oils of rosemary, lemons, &c.—consist of the two elementary substances, carbon and hydrogen only. In this fetid oil of garlic there also exists a compound consisting of carbon and hydrogen only, to which, from the generic name (*Allium*) of the plants in which it is found, the name of Allyl has been given. This substance, however, is united with sulphur in the oil of garlic, and has not an agreeable but an intensely fetid odour. This compound oil is called by chemists *sulphide of allyl;* and it is this substance which exists in garlic, and gives both to garlic and the onion their peculiar smell. The chive, the shallot, the leek, the rocambole, and the onion (*Allium leptophyllum*), which is eaten by the hill-people of India, all derive their smell from the same sulphur-containing oil of garlic. So do *Thlaspi arvense, Alliaria officinalis,* and many other plants. The relative mildness of these several vegetable productions, as well as that of different varieties of the common onion, depends upon the proportions of garlic oil they severally contain. And the bad smell of the breath after eating any of these plants is caused by the constant presence of a small quantity of this oil in the air we exhale from our lungs.

This strong-smelling compound, by the intensity and persistence of its odour, reminds us of the animal perfumes—musk, civet, and ambergris—described in the preceding chapter. Like musk, also, its exudes through the pores of the skin of the garlic-eater, giving its smell to the perspiration; and, on the other hand, a garlic poultice applied to the skin affects the breath; while, like the narcotic principles of opium,[1] it passes, probably unchanged, into the milk of the animals which swallow it. And both the intensity and adhesiveness of its odour are shown by the well-known fact that a knife which has been used to cut an onion retains for a long time, and communicates to other substances, the smell and taste of this oil, though it loses it when plunged for a little while in fresh earth. So powerful and persistent is the odour of alliaceous plants, that it may be recognised in the ex-

[1] See "The Narcotics we Indulge in."

creta of persons who have consumed the oil only in the form of a sauce into which a chive or an onion has been dipped.

It is not unworthy, also, of the attention of the reader, that, as the most fetid mineral smells I have described are compounds of sulphur, so this fetid vegetable oil of garlic is also a compound of sulphur. We shall have occasion to remark a similar connection of sulphur with other evil smells, both natural and artificial.

2°. *Asafœtida* is the concrete juice of two umbelliferous plants, *Narthex asafœtida* and *Scorodosma fœtida.* The former grows in Western Thibet; the latter on the steppes of the Caspian. It is probable that two other umbellifers also yield this resin. It is collected by cutting the stalk of the plant across immediately above the root—as represented in the woodcut (fig. 82)—leaving the root in the ground, and scraping off the sap as it flows upwards and dries on the cut surface. It possesses an odour similar to that of garlic, but still stronger, more fetid, and generally much more disagreeable to Europeans. On the borders of Asia, however, the concrete juice is not considered unpleasant. On the contrary, it is extensively collected, sold, and used as a condiment for food.

Fig. 82.

The Asafœtida plant.
a, Root, with the crown cut off, to allow the gum to exude; *b*, Crown, with root-leaves; *c*, Flowering stem.
Scale, 1 inch to a foot and a half.

When this resinous substance is distilled with water, it also yields a volatile oil in small quantity. On cooling, this oil becomes solid, and gives off, in a concentrated form, the fetid odour of the natural drug. Its smell has a certain resemblance to that of garlic, but it is still more offensive; and it contains, like that oil, a compound of carbon and hydrogen united with sulphur. Then, too, the oil obtained by distilling black mustard seeds, *Sinapis nigra,* with water, contains allyl and sulphur, though in this pungent oil nitrogen is present as well.

Two circumstances are interesting in connection with these compound oils and the condiments in which they occur.

First, That vegetable productions, so unlike to each other as the onion and garlic, which belong to the Lily Order, the asafœtida plants which are umbellifers, and the mustards which are crucifers, should owe their powerful and peculiar smell and taste to compounds containing the element sulphur —an element which is rarely present in any vegetable or animal compound, except in small proportion, but which exists in oil of garlic to the extent of 28 per cent of its weight.

Secondly, That without any knowledge of the close chemical relations among the plants in question, different races of men, in different parts of the world, have long selected and largely used them as condiments to their food. The Englishman, to a certain limited extent, relishes his onion, and the Frenchman mildly flavours his more savoury dishes with a touch of garlic or shallot. The Russian soldier fries his black bread with oil and onions. And mustard is almost everywhere a favourite condiment. But in Portugal and Spain the onion and the garlic are the relishes of common and everyday life. This taste the Peninsula has probably acquired from Northern Africa. Over the whole of the latter region—from the shores of the Mediterranean to the sources of the Nile—garlic and the onion are most esteemed seasoners of the universal food; Arab, Moorish, and Ethiopian tribes equally delight in them;[1] and this taste is of very remote origin. The Israelites, during their sojourn in the wilderness, murmured, saying, "We remember the cucumbers and the melons, the leeks, the onions, and the garlic." Among the ancient Egyptians themselves, the onion formed an object of worship; and the modern Egyptians assign it a place in their paradise. To the present day, the onion of the Nile borders possesses a peculiar excellence and flavour. The Eastern Asiatics appear to require more powerful condiments. With them the asafœtida takes the place both of the milder onion and of the stronger garlic.

Strange that the peculiar taste for these compounds of sulphur and allyl should so extensively prevail, and that vege-

[1] Garlic and salt, placed under the tongue, are considered by the Arab as a cure for thirst and fever.

table productions, so unlike in external appearance, should have been selected for the purpose of gratifying it! As in the case of the beverages and the narcotics, men seem to have been led to this selection by a kind of human instinct, guiding them blindly, as it were, to plants which were capable of yielding to the body the same or similar chemical compounds.

And to facilitate, as it were, the guidings of this instinct —to afford the means of gratifying the natural craving— these garlic-smelling compounds appear to be much more extensively diffused throughout the vegetable kingdom than physiologists are yet aware of. Several species of *Petiveria*, which are common in the West Indies, in Brazil, and on the eastern slopes of the Andes, are possessed of a strong garlic odour. Such is the case with the *Petiveria alliacea*, the guinea-hen weed of the West Indies; with the *P. tetrandra;* with the *Seguiera alliacea*, the root, wood, and leaves of which have a powerful odour of garlic or asafœtida, and are employed to form medicated baths in Brazil; and with a species of *Petiveria* called *Ajo del monte*, which forms one of the giant ornaments of the Bolivian forests on the eastern slopes of the Cordilleras.

Future research will probably show that these compounds of allyl exercise a peculiar physiological action upon the system, by which certain of its natural cravings are allayed, and its general comfort promoted. This is rendered more probable by the remarkable circumstance that the many kinds of mustard—the use of which as condiments so extensively prevails—owe their peculiar properties to the presence of compounds of the same substance—allyl.

3°. *Horse-radish and Mustard.*—When the root of the common horse-radish is distilled with water, it yields a volatile oil, which possesses the pungent smell and taste of the natural root in a highly concentrated state. The smell is not disliked, I believe, by most people; but I mention the oil in this place, because it contains a compound body, isobutyl, which takes the place of the allyl existing in the oils of garlic and asafœtida. In the horse-radish, however, it is combined not only with sulphur, but also with nitrogen, to the presence of which much of the difference of properties possessed by the horse-radish are to be ascribed. The smell and taste of the oil it yields are

very strong and pungent, but it has little of the fetid character which distinguishes those of garlic and asafœtida.

Mustard owes its peculiar penetrating odour, burning taste, and blistering quality, to the presence of a volatile oil, containing nitrogen and sulphur, like that which is found in horse-radish. It may also be prepared by distilling with water the roots of *Alliaria officinalis*, and our common cress, rape, radish, and similar pungent plants. Mustard-oil contains allyl, and so is more nearly related to garlic-oil[1] than is the pungent oil of horse-radish. Yet to one or other of these oils the above-named and many similar plants owe their peculiar pungent virtue; and, as in the case of those which possess the garlic smell, it is probably an instinctive consciousness of their salutary influence upon the system that has led to the extended use of them all in so many parts of the earth. From the water-cress, *Nasturtium officinale*, a pungent oil (called *phenyl-propionitril*), containing nitrogen but no sulphur, has been obtained; the common garden Nasturtium, *Tropæolum majus*, yields a similar oil, called *phenyl-acetonitril*. Thus we have three groups of pungent oils closely allied in odour and taste. The first group, of which garlic-oil is the type, are organic sulphur compounds; the second group, which includes mustard-oil, is marked by the presence of sulphur and nitrogen; the third group, of which water-cress oil is an example, are organic nitrogen compounds.

4°. *The Stinking Goosefoot* (*Chenopodium vulvaria*), fig. 83, is another plant which has been long known for its disagreeable smell, comparable to that of putrid salt-fish.

If a portion of this plant be distilled along with a solution of common soda, a volatile alkaline substance passes over, which has the smell of stock-fish, of boiled crabs, of herring-brine, or of Findhorn haddocks which have been long kept. To this substance chemists have given the name of *trimethylamine*. It has been found in hawthorn-flowers and in many other plants.

One of the interesting circumstances connected with this vegetable product is, that if herring-brine be distilled in the

[1] The chemical expressions for these two allyl compounds will illustrate their differences:—

$\left.\begin{matrix} C_3 & H_5 \\ C_3 & H_5 \end{matrix}\right\} S$ is oil of garlic; $\left.\begin{matrix} C_3 & H_5 \\ C & S \end{matrix}\right\} N$ is oil of mustard.

same way along with soda, the same volatile substance passes over in still greater abundance than from the stinking goosefoot. In a living and growing plant, therefore, and in the substance of dead and decaying fish, one and the same chemical compound is naturally produced, and imparts to each the same well-known penetrating and offensive odour for which it is everywhere remarkable. The famous relish of the ancients, *garum*, prepared by fermenting fish in brine, contained the same alkaloid.

Fig. 83.

Chenopodium vulvaria—The Stinking Goosefoot. Scale, 1 inch to 6 inches.

The history of this substance (*trimethylamine*) presents also an interesting illustration of the way in which chemistry throws light on natural phenomena. It was formed and obtained in the laboratory by special chemical processes, and its peculiar properties were ascertained, before it was extracted either from the evil-smelling plant or from the decaying fish. It was the smell of the artificial compound which suggested first that it might possibly be the cause of the repulsive odour of the living plant, and, afterwards, of that of the dead animal. Subsequent research showed the correctness of these conjectures, by actually extracting it from both by the processes I have described. As is the case with some of the natural vegetable perfumes, therefore, we can now prepare by art the stinking constituent of the goosefoot, should its production ever be likely to lead to profit.[1]

The interest which attaches to the disagreeable-smelling compounds of this class is very different from that which distinguishes the compounds of allyl. The latter have been sought for and used most extensively: the former have been generally avoided; no instinct or experience of their good

[1] *Trimethylamine* is not the only substance known to be possessed of this fishy odour. Another volatile alkaline compound, called *propylamine* or *tritylamine*, is in smell scarcely distinguishable from trimethylamine. The two substances consist also of the same elements united together in the same proportions,—that is to say, they are *isomeric* (see above, p. 416). Their chemical relations, however, and their chemical constitution, are not identical. The grouping of the three atoms of carbon (C), nine of hydrogen (H), and one of

effects upon the system has hitherto led any tribe of men to seek after or indulge in the use of them.

I may suggest to the cook, however, as a possible use to which these fishy-smelling compounds may hereafter be put in the *cuisine*—the flavouring of *imitation* fish-cakes, crab, lobster, crayfish, and oyster-*patés*, fish-sauces such as the anchovy, &c. Such preparations as these, by the application of a little skill, may pass off at table, and be made to please the palate as well as genuine salt-water productions, though containing nothing that ever lived in the sea!

5°. *Carrion-plants.*—As the goosefoot smells like putrid fish, so some plants smell like putrid flesh. The flowers of the bladder-headed *Saussurea* have the smell of putrid meat; and the *Stapelias*, because of their putrid and disagreeable odour, are distinguished by the name of carrion-flowers. The fermented juice of the Mexican agave also, which forms the pulque so popular in Central America,[1] is remarkable for its odour of putrid meat. The Skunk cabbage of the United States and our common Henbane afford further examples of offensive vegetable odours akin to those of animals.

nitrogen (N), of which the two compounds consist, is thus represented respectively—

$$\begin{array}{lcc} & \text{Trimethylamine.} & \text{Propylamine.} \\ & \left.\begin{array}{ll} C & H_3 \\ C & H_3 \\ C & H_3 \end{array}\right\} N & \left.\begin{array}{ll} & H \\ & H \\ C_3 & H_7 \end{array}\right\} N \\ \hline \text{The sum being,} & C_3\ \ H_9\ \ N & C_3\ \ H_9\ \ N \end{array}$$

The meaning of this mode of rationally representing the composition of the two compounds is this—

$$\begin{array}{ll} C\ \ H_3 & \text{represents a group of atoms called } \textit{methyl.} \\ C_3\ \ H_7 & \text{,,} \qquad \text{,,} \qquad \text{,,} \qquad \textit{propyl.} \\ H_3N \text{ or } \left.\begin{array}{l} H \\ H \\ H \end{array}\right\} N & \text{,,} \qquad \text{,,} \qquad \text{,,} \qquad \textit{ammonia.} \end{array}$$

Now, if for one of the atoms of hydrogen (H) in ammonia we substitute one of propyl, we produce propylamine, represented as above; or, if for each of the three atoms of hydrogen we substitute one of methyl, we have trimethylamine, also as above represented. Such substitutions we can actually make in our laboratories; and thus we are enabled to form a rational idea of the way in which compound bodies may contain the same elements in the same proportions, and yet differ very much from each other in properties. See as to *Methyl*, &c., p. 464.

[1] See "The Liquors we Ferment."

The chemical compound, or compounds, to which this carrion smell is owing, are still unknown. It is produced as a natural secretion, so to speak, in the living *Stapelias*—as the result of fermentation in the juice of the agave—and as a consequence of putrefaction in dead and decaying flesh. It may either be the same substance which gives the smell in all these cases, or it may be caused by different substances of the same chemical nature—all belonging most probably to the same class of volatile alkaline compounds, as the trimethylamine of the goosefoot and the stock-fish.

It is interesting to trace close chemical coincidences like these between vegetable and animal productions as regards even things subordinate and disagreeable. They are at least more unexpected, and apparently less necessary, than those we have already had occasion to remark between the entire substance of the animal body, and the staple forms of vegetable food by which it is supported.[1]

We have seen in this and the preceding chapter how tastes differ in regard to sweet odours. The history of the Mexican pulque illustrates how the disagreeableness of a smell may also be a mere matter of taste. Some relish a slight taint in butcher-meat, or a game-flavour in wild animals, because it indicates, and is usually accompanied by, a greater tenderness of the flesh. And so, notwithstanding its fetid odour, the Mexican loves his native liquor, and rejoices in it above every other drink. We seem to love or detest the putrid taint, not because of any positively painful effect it produces upon our organs of sense, but because of the associations with which it is connected. Let the odour in early life remind the smeller of an agreeably acid, thirst-quenching, and exhilarating liquor, and it will ever after come to his nostrils as an agreeable perfume. Let it first reach his sense of smell, and become familiar to him as the repulsive emanation from a dead and decaying animal body, and it will always remind him thereafter of disagreeable death, of hated worms, and of the dread dissolution his own frame must eventually undergo. It will never be to him otherwise than as a noisome stench. So much are the indications of our senses dependent upon the circumstances in which, when consciousness first began to dawn upon us, we happened to have been placed.

[1] See "The Bread we Eat," and "The Beef we Cook."

III. Animal Smells.—Unpleasant odours natural to animals are familiar to the inhabitants of almost every part of the globe. The he-goat, the badger, and the polecat in this country, the skunk in North America, the beautifully striped *Viverræ* of the South American plains, and the great ant-eater from the same country, now to be seen in zoological gardens, are each characterised by peculiar and unpleasant smells. Some of them, as they pass along, even sensibly infect the air with their pestilential odour.

In the case of the goat it is probably the perspiration from the skin in which the bad-smelling substance resides. In the skunk it is lodged in a peculiar receptacle, from which the animal has the power of ejecting it at will—probably as a means of self-defence. The intensity and durability of the odour of the skunk remind us of the same properties in the more agreeable musk and civet, which are also of animal origin. The purpose of defence supposed to be served by the smell of the skunk, would seem to imply that it is naturally offensive to the senses, altogether independent of early association.

Fig. 84.

Mephitis americana—The Skunk.

Many other animals emit unpleasant odours from their skin, especially in the rutting season; but of the chemical nature or composition of the substances to which all these animal stinks belong, we are as yet entirely ignorant. One known chemical fact in regard to the smells themselves, however, is sufficiently remarkable. This is, that the entire effluvia given off by an animal is often affected not only by the general nature of the whole food that it eats, but by the introduction of most minute quantities of foreign substances into the stomach. Thus the swallowing of a little pellet of finely powdered sulphur frequently gives a decided and disagreeable smell to the whole skin, and for many days after. And what is still more remarkable, a single grain of a compound of the metal tellurium administered to a healthy man, will make his neighbourhood perfectly intolerable for

weeks, and sometimes even for months, after he has swallowed it.

Tellurium yields a large number of organic compounds, almost all of which, if volatile, are of a still more fetid and disgusting character than those produced by sulphur. With the compound allyl—already spoken of as the peculiar strong-smelling principle of garlic, asafœtida, and mustard—tellurium forms a compound body which, when vaporised, is more intolerably offensive still than the oils of garlic or asafœtida: telluride of methyl is also fetid and poisonous in a high degree. And if we cannot use such compounds as means of sensuous gratification, it may not be impossible to employ them as weapons of offence or defence. Imitating the natural habit of the skunk in this respect, we might far surpass it in the intensity and offensiveness of our artificial stinks. Squirted from the walls of a besieged city, projected into the interior of a fortified building, or diffused through the hold of a ship of war, the Greek fire would be nothing to them; and as for the stink-pots of the Chinese, they must be mere bagatelles to the stenches we can prepare.[1] It must be confessed, however, that it would be difficult to find persons willing and able to manufacture these noxious compounds. Moreover, these stinks are generally deadly poisons, and would be fatal in most cases to their preparers.

As there are insects which give off agreeable odours, so many are known which emit disagreeable smells. That of the common bug tribe (*Cimicidæ*) is probably more offensive, because of the unpleasant sensations which the smell recalls. The same is the case also with the tree-bug (*Pentatoma*), and with the flying bug, which is one of the insect pests of the Ganges about Benares. The last of these is a large hemipterous insect of the genus *Derecteryx*, which insinuates itself between the skin and the clothes. It diffuses a dreadful odour, which is increased by any attempt to touch or to remove it; but the natural dislike for its smell is no doubt increased by the other annoyances which the insect occasions.

In regard to the chemistry of insect-stinks, little is known beyond the observation that some of them contain nitrogen and sulphur.

[1] See the succeeding chapter.

IV. SMELLS PRODUCED BY DECAYING SUBSTANCES.—The most numerous class of disagreeable smells is that which is produced by the decay or decomposition of animal and vegetable substances. Our dislike of these smells arises partly no doubt from their being associated in our minds with unpleasant sights and ideas, and partly from their being found by experience to be injurious to human health.

1°. *The Putrefaction of Animal Bodies.*—The general nature and odour of the ill-smelling substances produced during the putrefaction of animal bodies are determined by the sulphur, nitrogen, and phosphorus which are contained in them. During their decay the sulphur combines with the constituents of the animal matter, and forms fetid compounds similar to those already described as occurring in the mineral and vegetable kingdoms. Compounds containing nitrogen, such as various salts of ammonia, are likewise formed. The phosphorus also enters into combinations scarcely less unpleasant and injurious. And with these classes of compound bodies are associated others peculiar to animal forms of matter, which have not yet been separately examined. All these unite in producing those mixed smells which distinguish so repulsively the natural decay of animal substances in the open air.

Of the presence of sulphur in such cases, a familiar example is presented by a rotten egg. When such an egg is broken, the smell of sulphuretted hydrogen is at once perceived, and a silver spoon put into it becomes black immediately from the action of sulphur. As the decay proceeds, other smells gradually become sensible, and these mingling with that of the sulphuretted hydrogen, occasion that increasing offensiveness which the rotten egg is known to exhibit.

In warm climates, decomposition of this kind proceeds more rapidly, and the strong-smelling substances are produced both sooner and in greater abundance. The intensity of the odours emitted, and the distances to which they are diffused through the air in hot countries, may be inferred from the extremely short period of time required to bring the vulture and the condor even from great distances. They scent afar off the decaying carcass, where the human organs refuse to give any indications of its presence.

Air, moisture, and a certain degree of warmth, are neces-

sary to the decay of animal bodies. If any of these three conditions be wanting, it either proceeds more slowly or ceases altogether. Thus, in cool dry vaults, dug in an absorbent soil, and through which a current of dry air passes, human bodies sometimes become dry before they have had time to decay, and gradually shrivel up into frightful mummies.[1] So in the dry air of some hot climates, as in the Pampas of South America, and on the borders of the African deserts, the flesh of animals can be dried and preserved for any length of time, without exhibiting symptoms of decay, or any manifest evil odour.

But where moisture continues present — even though warmth and air be in a great measure excluded—decay still slowly takes place, and substances of evil odour and malign influence continue for a long period to be produced and given off. The true chemical nature and exact composition of many of the volatile and gaseous substances, produced under these circumstances, are still unknown; but both theory and experience prove that they are injurious to human health. They are so, even when, from their extreme state of dilution, the organs of smell are naturally insensible to their presence, or when, by habit, they have become so. Hence the custom of placing graveyards in the neighbourhood of our dwellings, or of requiring people to sit for so many hours a-week over putrid family-vaults, or heaps of mouldering human dust—is as contrary to the dictates of science and enlightened common-sense, as it is to the often-repeated suggestions of sanitary experience. That the senses detect no danger, proves that the senses are not to be relied upon—not that even serious danger is absent.

2°. *The Droppings of Animals*, both while recent, and during the decay they undergo in the presence of air and moisture, are the source of some of the most unpleasant smells with which we become familiar in common life. These animal excretions emit certain strong-smelling substances which are common to them all, but each variety also gives off smells peculiar to itself.

[1] The reader who has spent a day at Bonn on the Rhine, will probably be reminded by this passage of the mummies in the church on the Kreuzberg, which strangers seldom fail to visit.

a. When in a state of fermentation, for example, all evolve ammonia;[1] but it escapes in especial abundance from horse-dung in hot stables, and from nightsoil in ash-pits and necessaries during warm weather. All also produce and give off the noxious sulphuretted hydrogen already described; but where nightsoil ferments in close places, such as cesspools and common drains, this sulphureous gas sometimes accumulates in sufficient quantity to strike down instantly the workman who is incautious enough to place his mouth within its reach.[2] Compounds of phosphorus likewise escape from all, and volatile alkaline compounds, which have not hitherto been particularly examined.

b. When recent or fresh, on the other hand, each variety emits its own peculiar odour. The droppings of the cow and the horse differ most distinctly in smell both from each other and from nightsoil. Goat's dung has a smell, which it imparts to plants manured with it, so as to give a perceptible flavour even to the tobacco-leaf. Pig's dung is to most people nearly intolerable, and even animals dislike it. It not only gives its flavour to tobacco, but, when properly applied, it drives away the wireworm from the carrot and the onion. The reader will not be surprised to learn that the chemical nature and composition of the compound bodies from which these noisome smells proceed, should still be in a great measure unknown.[3] However interesting, in a physiological and sanitary point of view, it would be to possess a complete knowledge of all the substances which animal

[1] Ammonia is the substance which gives its smell to common hartshorn and smelling-salts.

[2] The best and most ready antidote, when sulphuretted hydrogen has been inhaled, is chlorine gas, prepared by wetting a thin towel with vinegar, sprinkling a little chloride of lime between its folds, and causing the patient to breathe through them.

[3] Among the peculiar organic compounds contained in fresh nightsoil, is a crystalline slightly alkaline substance, which has been named *excretine*, and an acid called the *excretolic* acid. They are extracted from fresh fæces by alcohol, but little is yet known of them. Excretine is not contained in the urine, nor is it ascertained if it is present in the contents of the small intestines. The droppings of herbivorous animals contain no excretine. Those of the carnivorous mammalia contain a substance resembling it, along with butyric acid, which is not present in nightsoil. Those of the crocodile contain cholesterine and no urea; those of the boa, uric acid and no cholesterine—(MARCET).

droppings contain—of the mode of their production, and of the nature of their several actions on the animal economy—we must be content to wait while it slowly and gradually collects. The inquiry is of too repulsive a nature to be undertaken by any chemist whose love of knowledge, or desire to advance a favourite branch of the science, is not of a very ardent kind.

There are certain known differences, however, in the composition of the solid droppings of different animals, which must affect the nature of the smells they severally emit. Thus, man discharges through his kidneys a distinct proportion of the phosphorus contained in the food he eats; while the cow, the horse, and the sheep, emit mere traces of it in this way. Very nearly all the phosphorus which these animals eat, therefore, is rejected in their solid droppings; and inasmuch as the compounds of phosphorus, which are formed in decaying animal and vegetable substances, are generally distinguished by peculiar and offensive smells, it is easy to understand that the droppings of these animals, when they heat and ferment, must emit some—more or less nauseous, and probably injurious—odours, which are not to be recognised in similarly fermenting nightsoil.

CHAPTER XXVII.

THE SMELLS WE DISLIKE.

SMELLS PRODUCED BY CHEMICAL ART.

Smells produced by chemical art.—Seleniuretted hydrogen.—Phosphuretted hydrogen.—Mercaptan.—Kakodyl.—Alkarsin.—Cyanide of kakodyl.—Compounds of tellurium.—Interesting chemical relation between sweet odours and stinks.—Acrolein.—Offensive substances produced by destructive distillation.—Smells emitted by manufactories.—The sulphuric acid, soap, candle, vinegar, and glass makers.—Lead and copper smelters.—Such smells may and ought to be prevented.

V. Smells produced by Chemical Art.—In the preceding chapter I have mentioned incidentally, that though many natural smells are very offensive, yet that we can already produce others by art which are still more so. Indeed, were any useful purpose to be served by them, we could, by familiar chemical processes, add stenches almost inconceivably disgusting to those which have hitherto been prepared. A reference to a few only of those which are now well known in our laboratories, will satisfy the reader as to the resources of the chemist in the production of stenches.

1°. *Seleniuretted Hydrogen.*—We have seen that sulphur is a substance which forms many combinations distinguished by their disagreeable odours; and of these I have described sulphuretted hydrogen as one which both occurs in nature, and can be easily produced by chemical art.

Selenium is an elementary body which, though less abundant in nature than sulphur, resembles it very much in sen-

sible and chemical properties. Like sulphur, it also combines with hydrogen, and forms a poisonous gas—the seleniuretted hydrogen. But this gas greatly exceeds the sulphuretted hydrogen, both in its evil smell and in its noxious qualities. A single bubble of it allowed to escape into the air of a room, produces on those who breathe it all the usual symptoms of a severe cold and affection of the throat, and these symptoms do not pass off for several days. The singular virulence of this substance illustrates in a very striking manner the injurious influence which may be exercised over the health of the people by the presence of very minute portions of foreign bodies in the air we breathe.

2°. *Phosphuretted Hydrogen* is a gas in which phosphorus takes the place of the sulphur and selenium contained in the two gases above mentioned. It is easily prepared in the laboratory, and is possessed of a peculiar fetid smell. It is one of the compounds of phosphorus, also, which is naturally produced along with other disagreeable substances during the decay of animal bodies, and contributes to the repulsive character of the smells which decaying animal matter gives off.

The two metals, or semi-metals, arsenic and tellurium, also combine with hydrogen, and form gaseous compounds—the arseniètted and tellurotted hydrogens. These gases are so fetid and poisonous that chemists rarely venture to prepare them; and when they do so, it is only after taking careful precautions against their escape into the air of the room in which the experiments are made.

It is a common character, also, of all the five gases I have named, that they combine with other compound bodies, and especially with organic[1] compounds, producing new substances far more fetid than themselves, and possessed of stenches which cannot be described in words. To this class belong some of the following compounds:—

3°. *Mercaptan.*—Among organic substances of much importance in modern chemistry is a class of bodies to which the name of *compound radicles* is given. These bodies consist of two or more simple substances united together, and are therefore compound bodies; and yet behave, in many

[1] By *organic* is meant such as are derived from the animal or vegetable kingdoms, or such as contain carbon.

respects, as if they were themselves simple.[1] To this class of bodies belong those which I have had occasion to mention under the names of

ETHYL,	as existing in	*wine alcohol and ether.*
METHYL,	,,	*wood alcohol and ether.*
AMYL,	,,	*potato alcohol and ether.*
ALLYL,	,,	*garlic and mustard oils,* &c.

Among other properties which these compound radicles possess is that of combining with sulphur, and of forming with it new combinations of an extremely fetid character. Of this the sulphureous oils of garlic and asafœtida are natural examples.

When ethyl is combined artificially with sulphur, it forms what is called *ethyl sulphide*, and when with hydrogen as well, it forms *mercaptan*. This latter substance is a colourless volatile liquid, possessed of a most offensive, penetrating, and concentrated odour resembling that of onions, and adhering obstinately to the hair and clothes.

Now, the important points to be borne in mind here, are—

First, That a very large number of compound radicles are capable of combining with sulphur and hydrogen, and of thus forming substances analogous to this mercaptan.

Secondly, As the number of such organic radicles already known is very great, it is consequently in our power to form many mercaptans, all possessed of very offensive smells, but each distinguished by a shade of offensiveness peculiar to itself. The reader will by this example, therefore, see that in the compounds of sulphur alone the chemist has at his command a very large number of exceedingly foul smells.

4°. *Kakodyl.*—But arsenic may take the place of sulphur in all these fetid compounds, and produce new volatile substances of which the smell is absolutely insufferable, and which, besides, are deadly poisons. Kakodyl is the name given by chemists to one of the compounds which arsenic forms with the radicle *methyl.* It contains two atoms of methyl with one of arsenic. When this volatile substance

[1] That is, like the simple substances—hydrogen, chlorine, the metals, &c.—they unite with oxygen, sulphur, and other bodies, without being themselves decomposed, and form with them new compounds, possessed of acid or basic properties.

is exposed to the air, it takes fire. As it burns, the arsenic contained in it combines with oxygen, and forms white arsenic. This diffuses itself through the air, and, when drawn in with the breath, acts as a deadly poison. Kakodyl and its oxide are the chief constituents of *alkarsin* or *the fuming liquid of Cadet.* This liquid is prepared by heating white arsenic and acetate of potash together. It is volatile, possesses a peculiar garlic-like, fearfully offensive, insupportable, long-enduring smell, and its vapours act as a deadly poison.

Four compounds of arsenic and methyl are known, while other compound radicles, as ethyl, also yield, with arsenic, poisonous and fetid liquids, each having some offensive peculiarity of its own. Arsenic furnishes us, in fact, with as many varieties of fatal kakodyls and alkarsins, as sulphur with purely fetid mercaptans.

5°. *Cyanide of Kakodyl.*—Even at this point, our chemical resources are not exhausted. Cyanogen is a compound radicle which unites with hydrogen to form the deadly poison prussic acid. This cyanogen combines also with kakodyl, and forms what is called cyanide of kakodyl. Besides the fetid odour and fatal properties of kakodyl, this compound possesses a deadly quality peculiar to itself. When exposed to the atmosphere, it rises in the form of vapour. A few grains of this cyanide in the air of a room, suffice to produce giddiness, delirium, and numbness of the extremities. We have a double poison present, combining the properties of two of the most deadly poisons with which we are acquainted. Mercaptan and oil of garlic expel us by their insufferable stench. The kakodyls and their cyanides arrest our flight by almost as suddenly depriving us of life.

In the preceding chapter I have alluded to the use of unbearable stenches as weapons of defence. The substances I there alluded to were for the most part disgusting smells, not acting upon the system as inevitable poisons. These kakodyls and their cyanides might certainly be employed, could they be prepared and transported safely in sufficient quantities, still more efficiently in warlike operations; but how far the use of vulgar poisons in honourable warfare is consistent with the refinements of modern civilisation, is open to much doubt. There may not be much real difference

between causing death by a bullet, and by the fumes of deadly poison; and yet, to condemn a man "to die like a dog," does array death to him in more fearful colours.

Among the deadly chemical combinations which have been spoken of as ingredients in the proposed *asphyxiating shells*, the kakodyls and their compounds have held a prominent place. Whether the proposers of such asphyxiating projectiles have considered this metaphysical distinction between different modes of compassing death, or whether it has weighed at all with those whose office it is to decide as to their adoption, we have no means of knowing. According to the received form of retribution, however, in all such cases, the chemist who first suggested the use of such poisons to manufacturers of ammunition, is destined to perish by his own new weapon of destruction.

6°. *Compounds of Tellurium.*—I have already spoken of the metal tellurium as capable of producing compounds possessed of a most offensive odour. Certain odourless preparations of tellurium administered, by way of experiment, to persons in good health, form compounds—as sulphur not unfrequently does—within the body of the patient, which impart to his breath, to the perspiration from his skin, and to the gases produced in the alimentary canal, a disgusting fetor, which makes him a kind of horror to every one he approaches; and this lasts sometimes for weeks, though the dose of tellurium administered may not exceed a quarter of a grain. Such compounds, which generally combine with a most offensive odour decidedly poisonous qualities, it is no doubt within the power of chemistry to produce by artificial processes.

7°. *Compounds of Phosphorus* with the organic radicles have been prepared. One of these, *trimethylphosphine*, has an indescribably nauseous odour. It is a heavy colourless liquid, sometimes taking fire of itself in the air: it boils at a very low temperature.

It is instructive to recall the fact mentioned in the chapter on "The Odours we Enjoy," that many of the most fragrant liquids made by art, such as acetic and œnanthic ether, contain the very same organic radicles as the offensive compounds just described. Only in the case of the pleasant odours and essences the radicle is united with substances derived from

acids like acetic and butyric; while sulphur, arsenic, or phosphorus are present in the offensive compounds just described.

8°. *Acrolein.*—When glycerine is distilled in a retort over a quick fire, a liquid passes over, to which the name of acrolein has been given. This substance is volatile, possesses a strong, penetrating, peculiar odour, affecting almost immediately the nose and the eyes. A few drops in a room render the atmosphere insupportable. Its vapour inflames the eyes, and if much breathed, and in a concentrated form, causes swooning. Acrolein is closely related to the allyl compounds previously described; indeed it bears the same relation to allyl alcohol as aldehyde does to common or ethyl alcohol.

This substance represents another large class of artificial bodies possessed of evil odours, which are produced by the destructive distillation, as it is called, of vegetable and animal substances. Coal-tar, wood-tar, coal and wood naphthas, the oils obtained by the distillation of horns, hoofs, fats, &c., all afford examples of the varied and unpleasant-smelling products which are to be obtained by the process of dry or destructive distillation. They are all mixtures of several different substances, but the smells they severally possess are owing to the presence in each of them of one or more disagreeable compound bodies. Many of these contain carbon and hydrogen only, or these elements with oxygen; but amongst them a compound of sulphur called carbon disulphide occurs in some quantity. This has an intolerable odour of decaying cabbage.

It is unnecessary, indeed, to dwell longer on artificial substances which affect the sense of smell in an unpleasant manner. Enough has been stated to satisfy the reader that the chemist can prepare these bodies in far greater numbers than they are yet known to occur in nature, and with smells if possible still more insufferable.

VI. Smells produced by our Manufactories.—In this great manufacturing country some of these artificial smells materially affect, at times, the comforts of common life. They have justly, therefore, been regarded as nuisances, and have given rise to disputes and contentions which not unfrequently occupy the attention of our courts of law.

From our manufactories of oil of vitriol (sulphuric acid) fumes of sulphurous acid, and even of sulphuric acid, and oxides and acids of nitrogen, are occasionally poured out into the surrounding air.

The makers of common soda (alkali-makers, as they are called) no longer discharge from their tall chimneys those vapours of hydrochloric acid which formerly often blasted not only the yearly crops, but permanent hedgerows and full-grown plantations. But those potters who make salt-glazed stoneware still send out thick fumes of this noxious and destructive gas.

The smelters of lead and copper vomit from their furnaces fumes of deadly arsenic, of zinc, of sulphurous acid, and even of lead itself, which sensibly affect both animal and vegetable life in their neighbourhood.

The soap and candle makers dissipate into the air the volatile fetid substances which naturally exist in long-kept and rancid fats. As a result of some of these processes, also, they produce and send forth vapours of the irritating and unpleasant acrolein, to which reference was made in a preceding paragraph.

The distillation of wood for the manufacture of wood-vinegar—or pyroligneous acid, as it is called—is often attended by the emission into the surrounding air of disagreeable and unwholesome fumes.

The manufacturers of glass, even of plate and crystal glass, when their operations are carelessly conducted, discharge from their cones unpleasant—it may be injurious—smells.

There is scarcely a manufactory, indeed, which involves the immediate application of chemical principles—and this includes by far the greatest number—which, if carelessly conducted, may not become a source of real annoyance, or even of injury, to its neighbourhood. I speak from a very wide experience, however, when I say that the escape of injurious substances into the open air, from such works, is rarely necessary to the prosperity of the several branches of manufacture. For the comfort of common life, therefore, the intentional discharge of them into the atmosphere ought not to be permitted.

CHAPTER XXVIII.

THE SMELLS WE DISLIKE.

THE PREVENTION AND REMOVAL OF SMELLS.

Wide diffusion of evil odours.—Prevention of smells.—Decay prevented by freezing, by drying, by excluding the air, by salting, and by smoking.—Effects of charcoal.—Smell-disguisers or perfumes.—Smell-removers or deodorisers.—Charcoal; cause of its remarkable action.—Dr Stenhouse's charcoal respirator.—Peat, vegetable soil, and burnt clay.—Smell-destroyers or disinfectants.—Nitric oxide, sulphurous acid, hydrochloric acid, and chlorine gases.—The chlorides of lime, iron, and zinc, and sulphate of iron.—Carbolic acid.—Permanganates.—Hydrogen peroxide.—Iodine and iodoform.—Quicklime; its unlike action on fermenting and unfermenting matters.—Summary.

EVIL odours are equally penetrating with sweet smells. They diffuse themselves through the air, and affect the senses unpleasantly even when the absolute quantity of matter present is too minute to be detected by our most refined methods of chemical analysis. Unlike the sweet odours, however, they are produced everywhere around us, and are therefore a universal source of more or less perceptible irritation and annoyance. To prevent the introduction of evil-smelling substances into the atmosphere which surrounds us, and when present to remove them, has consequently been at all times an object of desire. The attainment of this object has been rendered both more easy and more perfect by the discoveries of modern chemistry.

I. The Prevention of Smells.—The smells which usually arise from the decay or decomposition of the bodies and droppings of animals can often be either arrested or altogether prevented. Extreme cold, for example, such as is sufficient to freeze and harden the dead body of an animal, will preserve it in a state of absolute freshness, even for thousands of years. In northern winters the freezing of flesh and fish is the common way of preserving it; and in the ice-cliffs on the banks of a Siberian river, the entire body of an extinct species of elephant has been met with, so little decayed as to be still greedily devoured by dogs. Even moderate cold, if accompanied by a drying wind, will prevent decomposition, the former retarding the decay till the latter removes the moisture which is necessary to its continuance. The cargoes of fresh meat brought to our island from distant countries are kept unchanged by means of cold. The heat of the meat-chambers in such vessels is withdrawn by means of the evaporation of very volatile liquids, such as condensed sulphurous acid gas, ether, or liquid ammonia. These liquids in being vaporised absorb heat and so produce cold. Or the total exclusion of air will have the same effect, as is seen in the tinned meat, now so useful not only in long voyages and in remote parts of the earth, but for bringing cheap and excellent supplies of animal food to our shores.

These modes of preventing decay illustrate what has been said of the agency of heat, air, and moisture (p. 458), in promoting the putrescent fermentation of animal and vegetable substances. When we freeze them, we arrest decay by removing the necessary heat; when we dry them, by removing the necessary moisture; and when we shut them up in sealed vessels, by excluding the necessary air.

But decay can also be prevented by the direct application of chemical substances. Such is done when flesh-meat is immersed in sugar, or when it is impregnated with common salt, or with a mixture of common salt and nitre. These substances fill the pores of the flesh, and thus preserve it by excluding the air. And they withdraw the moisture of the flesh, and render the latter less favourable to the development of those minute organisms, both animal and vegetable, which incite and increase decay.[1] Volatile tarry matters,

[1] See "The Beef we Cook."

such as creasote and carbolic acid, which are contained in the smoke from peat and coal, in wood-vinegar, and in the spirit which is distilled from coal or wood tars, act in a similar way. They combine with the fibre of flesh or fish, and retard its decay, until the removal of moisture by evaporation renders decay both slow and difficult. It is in this way that the smoking of fish or flesh contributes to a speedy *cure*, saving both time and salt, rendering the cure more certain, and adding at the same time an artificial flavour, which to many is very grateful.

Substances which thus retard decomposition are called *antiseptics*. Besides those I have mentioned, white arsenic, corrosive sublimate, the chloride of zinc, alum, alcohol, camphor, and many essential oils, possess antiseptic virtues. In common life, however, these substances are rarely employed; though in museums of natural history alcohol is much used for bottling up anatomical and other preparations—and arsenic, corrosive sublimate, naphthaline, sulphate of copper and camphor, for preserving insects and the skins of animals.

Charcoal, when recently burned, has much efficacy in preventing the offensiveness of animal decay from becoming sensible to the smell. Sprinkled in the state of powder over the parts of dead animals, it preserves them sweet for a length of time. Placed in pieces beneath the wings of a fowl, it keeps away much longer than usual any appearance of taint. Or if strewed over substances already tainted, or mixed with liquids which have acquired the unpleasant smell of decaying organic matter, it removes the evil odour, and makes them sweet again. It is for this reason our common water-filters are so frequently filled with small pieces of fresh charcoal.

In all these cases, charcoal appears to act rather as a smell-remover than as a decay and smell preventer. In what way it acts as a remover of smells will be explained in a future part of the present chapter.

Quicklime also possesses the property of retarding, and to a certain extent preventing, the decay of animal and vegetable substances. Its action, however, as we commonly use it, is of a complicated kind, and will be explained when we come to treat of the smell-destroyers.

II. The Disguising of Smells.—Where evil-smelling decay of any kind commences, or where volatile substances which disagreeably affect the organ of smell escape into the air from any source, we naturally desire to rid ourselves of the unpleasant sensation. This we generally wish, and always ought if possible to do, by removing the substance to which the noisome smell is owing. In the great majority of cases, however, we merely overpower or disguise it. We are content to mingle with the smell we dislike some odour we can enjoy, and to leave floating in the air around us the evil and the good together, to produce unheeded their natural effects upon the system.

Sweet odours are thus the natural disguisers of evil smells. They are the only resource of rude and dirty times against offensive emanations from decaying animal and vegetable substances, from undrained and untidy dwellings, from unclean clothes, from ill-washed skins, and from ill-used stomachs. The scented handkerchief in these circumstances takes the place of the sponge and the shower-bath; the pastille hides the want of ventilation; the attar of roses seems to render the scavenger unnecessary; and a sprinkling of musk sets all other stinks and smells at defiance. The "sixty stinks of Cologne" may thus be at once the parent and grand consumer of its artificial rivers of scented water. The fiercest demand for the luxury of civilised perfumes may exist where the disregard of healthy cleanliness is the greatest. Even the burning of incense at the altar may find a merely rational use in disguising the dank and unwholesome smells which damp floors and walls engender, and in hiding from the senses of the worshipper the noxious effluvia which slowly decaying bodies in hidden vaults are continually giving off.

However much, therefore, the employment of fragrant essences may add to the comfort of the cleanly and refined, they may only promote disease and discomfort among the ignorant and barbarous, by concealing the deadly malaria, or overpowering the noisome stench.

III. The Removal of Smells.—The absolute removal from the air—at least from any limited portion of it—of the greater number of the evil smells I have described, is, however, by

no means a difficult task: the substances by which this is effected are known in modern sanitary language by the name of *deodorisers.*

1°. *Charcoal.*—Of these deodorisers, or smell-removers, charcoal, in its various forms, is one of the cheapest, most abundant, and most efficacious. I have already spoken of this substance among the preventers of smells as being an apparent retarder of putrefaction. That it is so, however, is doubtful. Many regard it, on the contrary, as a hastener of decay; but as a remover of smells, its action and virtue are undoubted. Mixed with fermenting nightsoil, or with the contents of our common sewers, it sweetens them almost immediately, and it produces a like effect upon almost every variety of decaying animal and vegetable matter. Spread to a depth of two or three inches over a festering graveyard, or even over a decaying dead body, it is said to prevent any evil odours from rising into the air, or becoming sensible to the smell.

Animal charcoal—such as is produced by the charring of animal substances out of contact with the air—peat-charcoal, seaweed-charcoal, and the black powder obtained by charring together a mixture of earth and vegetable matter, are more efficient in this removal of smells than common wood-charcoal, however finely it may be powdered. It is this power of absorbing evil odours which has recently recommended peat and seaweed charcoal so strongly to the sanitarian for removing the smells of graveyards, cesspools, drains, and other places where filth has been permitted to accumulate. And it might be employed in absorbing the valuable liquids which escape from stables and fold-yards.

This remarkable action of charcoal is the result of three properties, the influence of each of which it is important to distinguish. These are—

a. Its remarkable porosity. In consequence of this, it absorbs gaseous substances in large quantity, and condenses them in its pores. A cubic inch of dense charcoal, made from the shell of the common cocoa-nut, will absorb nearly 172 cubic inches of gaseous ammonia, 80 of sulphuretted hydrogen, 78 of carbonic acid gas, 18 of oxygen, and 21 of carbonic oxide. This property is for the most part physical, and is possessed in a considerable degree by other porous substances.

b. The special affinity which charcoal exhibits for certain strong-smelling and colouring substances. So powerful is this affinity, that if a table-spoonful of finely-powdered animal charcoal—or twice as much of newly-burned wood-charcoal—be shaken up with a pint of stinking ditch-water, and the mixture filtered, the water will pass through bright, clear, and with little of either taste or smell. If, instead of dirty water, we take porter or port wine, smell, taste, and colour will in like manner disappear. This property is in great measure physical or mechanical, since the colouring matters removed can be recovered for the most part unchanged. They have been withdrawn, not altered.

c. The oxidising influence it appears to exercise upon the substances it absorbs. Many of these substances, whether gaseous or solid, whether strongly smelling or strongly colouring, as soon as they are laid hold of by the charcoal, begin to unite with oxygen, to lose their characteristic properties, and to change into new chemical compounds. An example of this action is furnished by a piece of charcoal plunged first in sulphuretted hydrogen, and then in oxygen. It absorbs both, and becomes hot, while the hydrogen turns to water with some of the oxygen, and the sulphur to sulphurous acid gas with the remainder. This action is purely chemical. But the charcoal does not *pro*duce, it only *in*duces it. It condenses these gases within its pores, and when brought in contact in this condensed state, they act upon each other so as to produce sulphurous acid gas and water. In like manner, solid substances are oxidised or changed, but the smell-removing influence of charcoal ceases when its pores become filled with the new and fully oxidised compound thus produced.

I have said that it is doubtful if charcoal, though it keep fresh meat sweet, really does preserve it from decay. It is in consequence of the oxidising influence just described that many regard it as in reality hastening the decay of animal bodies.

Dr Stenhouse availed himself of the absorbent property of charcoal in the construction of a respirator, which, as a remover of noxious vapours and unwholesome smells from the air we breathe, is a sanitary instrument of great value. This respirator (figs. 85 and 86) consists essentially of a hollow

case made of fine flexible wire-gauze. Internally it is about half an inch wide, and of sufficient length and breadth, when

Fig. 85.

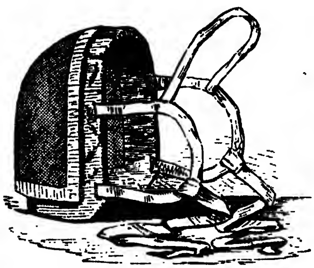


Fig. 86.

folded over the lower part of the face, to cover closely either the mouth alone, or both the mouth and the lower part of the nose. The hollow space is filled with coarsely-powdered charcoal, and the instrument, like the common metallic respirator, is fitted to the face, and fastened over the head by attachments of ribbon. Through this powdered charcoal the breathing is effected. All the air that enters the lungs must pass through this charcoal sieve, and in so passing is deprived of the noxious vapours or gases it may contain. Whether, as in the case of cesspools, laboratories, hospitals, dissecting-rooms, sewers, and the holds of ships, these vapours be perceptible and offensive to the smell—or whether, like the miasms and malaria which marshes and festering ponds exhale, they be imperceptible to the senses—still the charcoal, it is alleged, will arrest them, and thus secure the wearer of the respirator from their irritating and unwholesome influences. After a while the charcoal-powder becomes saturated, or too old to act with efficiency; but an ounce of powdered wood-charcoal renews it, or the old charcoal may be heated to redness in a close vessel, and the instrument is itself again.

The invincible obstinacy of the labouring classes in adopting novelties has prevented the general employment of this cheap and effective respirator. It would be of great service in hospitals, sick-rooms, and chemical factories. And should its powers in arresting unperceived malaria be established by

experience, how important will it become to the traveller in unwholesome marshy regions, like those along the foot of the Himalayas, those which skirt the lower course of the Niger and the Mississippi, or such as spread over south European flats and valleys, like the Pontine and other Italian marshes, and the Dobrudscha towards the mouth of the Danube! May it not even prove a safeguard and health-preserver in many of those inhabited parts of the world where rich crops are dearly bought at the expense of rarely absent fevers, aguish fears and tremblings, debilitated frames, and short, unhappy lives?

2°. *Peat, Vegetable Soil, and Burned Clay.*—Peat, if dry and in powder, acts also as an absorber of smells. It is likewise of an acid nature, which enables it to combine with and thus to retain ammonia and many of the stinking substances it has absorbed. Earth rich in vegetable matter acts in a similar manner, and even some varieties of clay purify the water that filters through them. The porous mass obtained by burning together clay and vegetable matter under cover has also, as I have already remarked, a powerfully absorbent property; and the coal-cinders we throw into our ash-pits, by their porousness retain a portion of the effluvia which escape from the other offal with which they are mixed, and thus lessen its offensiveness.

It is a valuable property of charcoal, cinders, peat, earth, and clay, burned or unburned—when saturated with ill-smelling substances, such as those I have mentioned—that, when conveyed to the land, they fertilise the soil with which they are mixed, and gradually yield, as valuable nourishment to growing plants, the disagreeable forms of decaying matter which they had previously absorbed or taken up.

IV. The Destruction of Smells.—Substances that absorb and remove evil-smelling bodies do not necessarily destroy their smells, or take away any poisonous quality they may possess. Thus water absorbs sulphuretted hydrogen, but acquires, at the same time, its offensive smell and its poisonous property. Heat the impregnated water, and the gas escapes again into the air with all its original qualities. Bodies which act as water does in this case, remove, but do not change, the smelling substance.

But if into water or air which smells of sulphuretted hydrogen a little chlorine gas be introduced, the smell of rotten eggs will disappear almost instantaneously. The sulphuretted hydrogen is decomposed and destroyed. It no longer exists, and consequently both its smell and poisonous influences are gone.

Water, as regards sulphuretted hydrogen, is a smell-remover or *deodoriser*. Chlorine acts upon the same substance as a smell-and-poison destroyer, or *disinfectant.*

This distinction is not without its practical importance. Water, soil, and other absorbents, may remove and retain noxious substances so long as cold or wet weather continues; but let heat and drought return, and forthwith from water and soil they steam up again more or less unchanged. Hence those reeking miasms which spread mortal fever and chattering ague over entire provinces. The disinfectant decomposes and destroys the evil compound, so that no change of circumstances can bring it into activity again.

All disinfectants act chemically. They either decompose, or they combine with the noxious substances, and produce new compounds, which, if not always void of smell, are comparatively harmless in their action upon the human body. I shall mention those which are at once most efficacious and most easily accessible.

1°. *Nitric Oxide Gas* is produced when the common aquafortis of the shops is poured over pieces of copper in a glass or earthenware vessel. As it rises into the air it combines with oxygen and water, and forms red fumes of a strongly acid nature (nitrous acid), which diffuse themselves through the atmosphere. These fumes have a somewhat uncertain action upon the noxious substances, contaminating the air; moreover, they provoke cough, and cannot be breathed with safety, and they corrode nearly all metallic substances with which they come in contact.

2°. *Sulphurous Acid Gas* is produced when sulphur is burned in the air. It is one of the offensive substances I have described among mineral smells. In large quantity, it is both noxious and offensive to breathe, but as a disinfectant it may often be used with advantage. Hence the very common practice of fumigating with burning sulphur, a sulphur pastille being one of the best and neatest forms of using this substance.

The first effect of this gas, when diffused through the air, is to overpower all other smells, and thus to make them imperceptible: it acts as a smell-disguiser. Its next effect is chemically to decompose or destroy such offensive substances as the sulphuretted and phosphuretted hydrogens of which mention has been so frequently made; and as it is of a strongly acid nature, it as speedily combines with alkaline vapours—such as those which contain ammonia, or the evil-smelling body which gives its odour to stinking fish (p. 452), and removes their smells. It exercises also a special action upon many organic substances. This may be seen by holding a burning sulphur-match beneath a red rose, which it generally whitens, and by the change of colour it produces upon many other flowers. It is also seen in the common use of the fumes of burning sulphur for bleaching silk and woollen goods, and for whitening the straw employed for ladies' bonnets. It is believed, therefore, to be capable also of destroying many noxious substances of organic origin which may happen to be present in the air with which it mingles. And moreover, it is found to be fatal to many, if not all, of those minute forms of animal or vegetable life to which a number of endemic diseases are now with good reason attributed. The germs by which these diseases spread are killed by this gas.

On the whole, sulphurous acid has much to recommend it. It is also cheap and universally accessible. The objections to the use of the gas are, that it is itself unpleasant and repulsive—that when employed for disinfecting purposes, the inhabitants of a house must be excluded till the operation is concluded and the apartments fully ventilated—that it corrodes metallic surfaces, and leaves behind it for some time traces of its own disagreeable smell.

3°. *Hydrochloric Acid Gas* is produced when the oil of vitriol of the shops (sulphuric acid) is poured upon common salt. It unites with the moisture of the air the moment it is disengaged, and forms white, strongly acid fumes, which provoke cough and cannot be breathed. These acid vapours will undoubtedly act upon and destroy many kinds of strong-smelling and noxious gases and vapours which may be present in the air. The objections to its use, however, are the same as those against the use of nitric oxide, and of equal strength.

4°. *Chlorine Gas* is obtained when the common spirit of salt (hydrochloric acid) of the shops is poured upon finely-powdered black oxide of manganese; or when this powdered oxide is mixed with the common salt before pouring oil of vitriol upon it, as in the preparation of hydrochloric acid gas above described.

Chlorine is a heavy, greenish-coloured, suffocating, and strongly-smelling gas. In a dilute state, its smell is now familiar to most persons as that given off by the common chloride of lime of the shops.

This gas decomposes sulphuretted hydrogen, phosphuretted hydrogen, ammonia, and nearly all the other gaseous compounds and evil-smelling vapours which escape from decomposing animal and vegetable matters. It acts, indeed, upon all organic substances almost without exception. Hence its extensive use for bleaching cotton, linen, fatty bodies, and a host of other vegetable productions used in the arts. It is also a most powerful agent for the destruction of disease-germs.

Chlorine has been long employed as a remover and destroyer of unpleasant smells. It is probably the most generally efficient for this purpose of any gaseous substance with which we are acquainted. And besides its efficiency, it is further recommended by being easily and cheaply prepared; by producing its good effects even when so much diluted with air as to be breathable without injurious effects. It can thus be used within a building without displacing its inhabitants, and with little inconvenience even in the chambers of delicate invalids. In this dilute state, also, its use is free from almost every other objection. For though it does corrode metallic substances, its evil effects in this way are much less sensible than those of any of the other gases already mentioned.

The use of these gaseous substances is restricted almost entirely to the removal from the air of evil-smelling and noxious substances which are already mixed with it. But a service often demanded of disinfectants, and one not less important for sanitary objects, is to prevent the emission of these substances into the air altogether—to arrest, confine, and fix them down among the festering substances which produce them. This service can only be rendered by bodies

which are in the solid or liquid state, and can therefore be mixed or spread over the decaying matters from which the hurtful emanations proceed.

A satisfactory disinfectant of this kind must also possess at least two well-marked chemical properties. These are distinctly pointed out by the general chemical characters of the evil-smelling substances to be acted upon.

These substances, as they arise from decaying vegetable and animal bodies, are of three chemical kinds. They are either alkaline substances, like ammonia and trimethylamine (p. 454); acid substances, like sulphuretted hydrogen; or neutral substances, like the sulphuretted hydrocarbons. An effective and complete disinfectant must be able either to decompose or to combine with all these classes of compound bodies. And economically, its value will be further increased, if, while it effects these chemical purposes, it at the same time produces a new substance which is not offensive in any way; and still more if it produce one that is positively useful.

5°. *Chloride of Lime* possesses the chemical qualities of an efficient disinfectant in a high degree. It consists of lime and chlorine: of these, the lime combines with acid bodies, while the chlorine either combines with or decomposes the alkaline compounds represented by ammonia. And at the same time it possesses a remarkable power of *oxidation;* it burns up many of the offensive neutral bodies evoked during decay. It exerts this influence even upon sulphuretted hydrogen. This oxidising action of chloride of lime may be, in some cases, thus explained. Carbonic acid gas unites with its lime and frees its chlorine, which then unites with the hydrogen of water, liberating the oxygen of the latter. It is therefore generally and deservedly esteemed as one of the best, most efficient, and most manageable of our solid disinfectants. Spread in the solid form upon any fermenting mass, it destroys the noxious bodies as they are formed. Dissolved in water, and sprinkled over bad-smelling chambers, or mixed with more or less fluid collections of putrid matter, it brings sweetness everywhere. Fetid odours and poisonous qualities alike disappear before it. Only its comparatively high price prevents its being employed for sweetening our common sewers, garbage-heaps, and cesspools.

The results of its action have the further advantage, that they are not offensive either to sight or smell; but they do not possess the same fertilising richness as the mixed heaps obtained by the use of powdered charcoal. Its chlorine decomposes ammonia, and hence fermenting heaps treated with chloride of lime will be poorer in this ingredient so valuable to vegetation.

6°. *The Chlorides of Iron and Zinc*, especially when made somewhat acid, are, chemically speaking, almost equally efficacious. They have the disadvantage, however, that they run to liquid (deliquesce) rapidly when exposed to the air, and cannot well be preserved in the solid form. Hence they are generally dissolved in water, and used in the liquid state. It is an objection to the liquid chloride of iron that it causes a brown stain wherever it is spilt, and makes the fermenting substances to which it is applied of a black colour. The zinc liquid is itself colourless, colours nothing when it is spilled, and when poured upon the foulest decaying substances, only covers them with a white cream. These properties cause it to be preferred to the iron liquid, where economy is not an object, the chloride of zinc being the more costly of the two.

The solution of chloride of zinc forms "Burnet's Disinfecting Fluid." It has the property of not only deodorising and disinfecting, but of actually preventing decay, especially in vegetable substances. Hence, like corrosive sublimate and creasote, it has been extensively used for saturating timber, especially such as is to be used in circumstances in which timber is liable to rot. Sulphate of iron, or common green vitriol, is nearly equal in efficacy to the chloride of iron, but, except that it does not run to a liquid, is liable to the same objections. It has been used for removing the offensive odour of sewage in the Thames, and for similar purposes. But though it fixes ammonia as sulphate, and turns sulphuretted hydrogen into sulphide of iron, yet it does not prevent these matters from again becoming a nuisance, as chloride of lime does.

7°. *Iodine*, and one of its compounds, known to chemists by the name of iodoform, have been recommended as smell-removers and disinfectants; but however efficient, their expense must always exclude them from anything like extensive use.

8°. *Quicklime*, though so abundantly used during the cleansings to which the cholera-visitations have given rise, is less efficacious either as a remover or a destroyer of smells than any of the substances above mentioned. It is usually employed in the state of newly-slaked lime. In this state its action on animal and vegetable substances is twofold.

a. If the substance be fresh, it retards and partially prevents its decay. This is its effect upon flesh, blood, recent animal droppings, nightsoil, urine, &c. And as decay afterwards slowly comes on, it modifies the nature of the chemical substances produced, so that ammoniacal and other strong-smelling compounds do not arise from them, or at least not so sensibly as would otherwise have been the case. To *fresh* animal matters, therefore, quicklime, as a preventer of smells, is a very proper addition.

b. But if the substance have already begun to ferment, the lime acts very differently. It is strongly alkaline, and therefore, while it combines with the acid substances which the fermented matter may contain, it sets free the ammonia and other volatile strong-smelling alkaline compounds which may have been formed in it. Thus its first effect, when laid upon fermenting animal and vegetable refuse, is to increase the quantity of odoriferous matter which exhales, and consequently the intensity of the smell. Its next effect is to retard further decomposition and to change the chemical nature of what does afterwards rise into the air, as to make it both less disagreeable to the smell, and less injurious to the health.

Spread in a layer over a foul heap, therefore, it disengages a great amount of strong-smelling volatile matter; but this being once carried off by the wind, the covered heap remains comparatively quiescent. The lime arrests and unites with the sulphur and phosphorus as they approach the surface of the heap, and disposes the substances containing nitrogen to change into nitric acid, and combine with itself, instead of dissipating themselves into the air in the form of ammonia and other volatile alkalies. With the exception of the first loss it occasions when laid on fermented matter, therefore, lime retains in the decaying heap the greater part of what makes it of value to the farmer, provided, that is, the access of rain is prevented.

It is in close and confined places, where the wind has not ready access to sweep away what is at first evolved, and to masses of putrid semi-fluid matter, such as collections of nightsoil, that the application of quicklime may prove most unpleasant. When used in such circumstances, it should be strewed on lightly, or after the heap has been spread over with straw, peat, sawdust, or other similar substance; and the mass should, if possible, be entirely covered over with it, and left afterwards undisturbed.

9°. *Permanganates and Manganates.*—Under the names of Condy's purple and green fluids, certain compounds containing an alkaline metal, such as sodium or potassium, united with much oxygen, and the metal manganese, have come into considerable use as deodorisers and disinfectants. Not being volatile like chlorine, of course such a substance as potassium permanganate cannot search out and destroy those impurities which are dispersed in the air. But if a solution of this substance be placed in a saucer, the air that passes over it may be purified; while linen or infected clothes may be cleansed from taint by being soaked in it. Like chlorine, it acts by burning up or oxidising the poisonous or offensive matters with which it comes in contact. But it is rather costly, while its action is less energetic than that of chlorine.

10°. *Hydrogen Peroxide.*—Under the name of "Sanitas," a watery solution of hydrogen peroxide has been introduced into commerce. It is a useful material for removing taints, smells, and poisonous matters of many kinds; but is, however, costly in comparison with other deodorisers and disinfectants. It has been recommended as a mouth-wash, and for cleansing the teeth. Its active ingredient, hydrogen peroxide, readily gives off oxygen, and then oxidises the impurities with which it comes in contact. Sanitas, or the ordinary commercial solution of peroxide of hydrogen, is made by blowing air through a mixture of turpentine and water. In this way part of the oxygen in the air combines with water to form oxidised water or hydrogen peroxide, while another part produces from the turpentine an acid called camphoric acid.

11°. *Carbolic Acid and Creasote.*—The smell of wood-tar is due in great measure to the presence of two substances endowed with remarkable powers of arresting decay and change in organic matters. The more important of these two tar-

constituents goes under the names of *carbolic acid* and *phenol*. It occurs abundantly in coal-tar, which is now its chief source. When pure it is a white crystalline solid, melting at a gentle heat, boiling at a rather high temperature, and dissolving to the extent of 4 parts in 100 of cold water. When perfectly pure its smell is powerful, but not offensive; but even the best carbolic acid of commerce contains naphthaline and other disagreeably smelling substances. Now the great efficacy of carbolic acid is as a disinfecting agent: it does not oxidise organic impurities, and its chemical affinity for ammonia and bases is but slight. But it destroys germs of many kinds, the poisons of many diseases of men and animals, by coagulating or curdling their chief constituents, and so rendering them incapable of further growth. This at least is the most prominent character of carbolic acid. It also arrests decay as it arrests growth. It is a powerful caustic, even dissolving the skin to which it is applied. It has been put to a considerable number of uses in medicine and surgery, having been found efficacious as an application to decayed teeth, for inhalation in hooping-cough and sore throat, and being given internally in some forms of indigestion. But its medicinal activity is to be mainly explained by its power of coagulating and rendering insoluble organic matters related to albumen, and so of arresting change, and the growth of those vegetable and animal organisms which accompany and favour decay and disease.

It has been urged against the use of carbolic acid that it is a dangerous irritant poison. People have been killed by drinking it instead of whisky! A taste must be somewhat vitiated by dram-drinking if it cannot discern the difference! Nor need the carbolic acid be kept in a liquid or concentrated form: it may be prepared so as not to admit of being drunk at all. But the objections are too trivial to need refutation, and are generally urged by persons interested in the sale of competing disinfectants.

Besides carbolic acid, creasote, the mixture of this acid with another similar compound, called cresylic acid, is also a good antiseptic and disinfectant. So are a number of essential oils or substances extracted from them, as eugenol from clove-oil.

In using disinfectants and deodorisers, their chemical

nature and the special objects we have in view should both be considered. We cannot use a fixed substance like a permanganate to purify the air, nor must we mix two substances of this group together, unless we are sure that they will not interfere with one another. So burning sulphur or sulphites may be used with carbolic acid; but none of these substances can be employed at the same time as chloride of lime or the permanganates, though these latter substances may be associated with one another.

When large operations are to be carried on, as in the sanitary cleansing of towns, charcoal-powder, peat, dried earth, the smother-burned mixture of clay and vegetable matter, and quicklime, are the cheapest and most available. The two former are excellent and unexceptionable; the latter has the disadvantage, that from substances already fermenting it drives out for a while more powerful odours than they naturally emit, and requires, therefore, to be used with care and caution. In their chemical influence upon the after-decay of the substances to which they are applied, charcoal and quicklime, as I have said, resemble each other very much. A mixture of lime, carbolic acid, and sulphite of lime (calcium sulphite), is also an excellent disinfectant.

For the sake of clearness I may briefly recapitulate the several classes of substances I have endeavoured to classify and distinguish in the present chapter. Those are—

1°. *Decay-preventers, or Antiseptics*, including common salt, saltpetre, white arsenic, corrosive sublimate, the chlorides of zinc and iron, sulphate of iron, carbolic acid and creasote, alcohol, camphor, the essential oils, and, in certain cases, quicklime.

2°. *Smell-disguisers, or Perfumes.*—To this class belong the greater part of the substances already described among the odours we enjoy.

3°. *Smell-removers, or Deodorisers.*—Among these, charcoal, peat, fresh and charred, clay burned, unburned, or smother-burned along with vegetable matter, and other porous substances, are the most important.

4°. *Smell-destroyers, or Disinfectants*, which not only absorb and remove evil smells, but decompose and change, and thus altogether remove the substances which produce them. To this class belong nitric oxide, sulphurous acid, chlorine, the

chlorides of lime, zinc, and iron, the sulphate of iron, iodine, hydrogen peroxide, permanganate of potash, and quicklime. Carbolic acid and creasote unite to a remarkable extent the characters of antiseptics and disinfectants.

To disinfect, a substance must chemically change the noxious compound and produce a harmless one. All chemical change does not involve the latter result, as some poisonous vapours may be chemically changed, and remain poisonous still. Such is the case with those of kakodyl and the cyanide of kakodyl, described in a previous chapter (p. 464). But the disinfectants described and recommended in the preceding pages, are really poison-destructive as regards all *natural* evil smells and miasms with which we are yet acquainted.

CHAPTER XXIX.

THE COLOURS WE ADMIRE.

Animal pigments or colouring matters.—Red pigment of blood or hæmaglobin.—Turacin, a red pigment containing copper, found in certain feathers.—Pigmentum nigrum.—Chlorophyll, or leaf-green.—Colein, the pigment of many fruits and flowers.—Alizarin from madder.—Coal-tar dyes.

There is no recent application of the science of chemistry to the peaceful arts of common life more interesting and more instructive than the manufacture of colouring matters. Not only have new dyes, possessed of every hue of the rainbow, been produced out of that unpromising and repulsive mess which goes by the name of coal-tar, but the chemist has found out the way to obtain, from the same source, the very substance which gives to madder-root its value as a dye-stuff. For his artificial product is no mere imitation of the natural colouring matter formed by this plant, the *Rubia tinctorum* of botanists—it is identical with it in every respect. And besides making new pigments; and preparing, by the methods of the laboratory, the actual colouring substance of a vegetable organism, the chemist of the present day studies with minute care the various compounds to which so many animals as well as plants owe their diversity and beauty of tint. Indeed the whole subject of colouring matters has now become so complex that a large volume would not suffice for its adequate treatment. To present to the readers of this chapter a few specially characteristic examples, illustrative of recent advances in our knowledge of the properties, the production, and the uses of pigments,

both animal, vegetable, and artificial, is the utmost that can be here accomplished.

1°. Of animal pigments first; and amongst these the red colouring matter of blood naturally occupies a conspicuous place. It is only of late years that the immense importance of the duties performed by that chiefest and most abundant constituent of the blood now known as *hæmaglobin* has been realised. If we take 100 grains of blood, perfectly fresh, we shall find that they contain some 15 grains of a red pigment — entirely present in what are called the red corpuscles.[1] This red pigment differs from all other constituents of the body of man in several important particulars. The presence of iron in it is perhaps the most striking feature of its chemical composition. But its most remarkable physical or physico-chemical property is its property of absorbing gases. On this latter property depends one of its main uses in the blood, for it carries oxygen throughout the body. The difference of colour between the blood of the arteries and that of the veins is due to the presence of this absorbed oxygen acquired in the lungs. Thus a kind of compound of hæmaglobin and oxygen gas is formed, which has a brighter red than hæmaglobin itself as it exists in the blood of the veins. This difference of colour is seen very plainly, even through the skin, when arteries and veins are compared; but when an optical examination of the two conditions of blood is made it is more conspicuously shown. And further, it is possible to add oxygen to venous blood out of the body as well as in, and thus to restore its colour to that of arterial blood; and the reverse process may be accomplished too. The following table shows, approximately, the proportions by measure of gases in the blood, nearly all of which are associated with the hæmaglobin—

Gases.	100 measures of Bright red arterial blood.	100 measures of Purplish red venous blood.
Carbonic acid gas. . .	50 measures.	60 measures.
Oxygen „ . .	20 „	10 „
Nitrogen „ . .	2 „	2 „

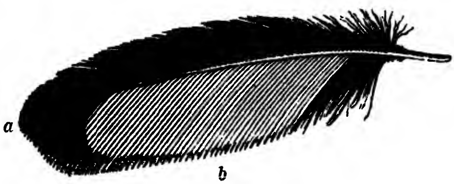
It has been said above that hæmaglobin contains iron. This metal, though present in very minute proportion, is an

[1] See Chapter XXXII.

absolutely essential part of the substance. The human body, at least that of an adult man weighing some 11 stones, will contain about 1½ pound of hæmaglobin, in which the iron amounts to no more than 40 grains. As nearly all kinds of vegetable and animal food contain distinct traces of iron, there is no difficulty in understanding the source of the iron in the pigment of the blood. Thus Boussingault found that 100,000 parts of potatoes contained 1½ part of this metal, and the same quantity of Beaujolais wine about 1 part. The other elements which are united to form hæmaglobin are the same in nature and proportion as those which are found in albumen (see p. 99), to which this colouring matter is nearly related. It ought to be mentioned that hæmaglobin can be obtained in crystals, but that in every form it is very prone to decomposition. All animals having red blood possess it, or a nearly identical compound.

2°. Another animal pigment of infinitely less importance than hæmaglobin, but having a still stranger composition, may be introduced here. It has nearly the same colour as arterial blood, and, like it, contains a metallic constituent. But, unlike hæmaglobin, this red pigment is of very rare occurrence in the animal kingdom, while the metal which is present in it is not iron but *copper*. This pigment, to which the name of *turacin* has been given, is found in the pinion-feathers of some eleven different kinds of birds peculiar to Africa, and known as Touracous or Plantain-eaters. About fifteen feathers in each wing present patches of crimson hue, or are almost entirely red.

Fig. 87



Wing-feather of a Touracou.
a, Black part, destitute of copper.
b, Red part, coloured by the cupreous pigment.

Clean one of these feathers (fig. 87) with water and acid and ether, and then boil it with water—the water becomes pale pink. Add a drop of hartshorn, or ammonia, or soda, or a particle of soap, and then in a few minutes the water will grow crimson, while the red parts of the feather will become white or nearly so,

the dark or black portions remaining unchanged. Touracous in captivity have been known to reduce their splendid crimson decorations to a shabby pink by too frequent ablutions with rain-water! The red pigment separates from its solution in ammonia or other alkali when a strong acid is added, in flocks, which may be dried into a rich crimson solid. This, when analysed, contains, along with carbon, hydrogen, nitrogen, and oxygen, about 8 per cent of copper, this copper being so bound up with the other elements present as to be incapable of removal by any treatment of the pigment short of its entire destruction.[1]

The existence of an animal pigment so rich in copper as turacin, offers many interesting problems for study. Traces of this metal seem generally diffused in most vegetables and many animals; but here are more than traces—weighable and visible quantities. It is true that these plantain-eaters have been seen to pick up in their native countries grains of malachite, the green mineral carbonate of copper; but we must rather look to the vegetable food they consume as the true source of this metal. And when the copper has been ingested, how does it find its way, in the complex pigment of which it is an essential part, precisely to those feathers, and to those barbs of feathers, and to those parts of such barbs, which are red, and not to the black portions? For if one of these feathers is burnt in a Bunsen gas-burner, not till the red part of the feather is reached will the green flash of the copper tinge the flame. However, in the *crest* of the violet plantain-eater (*Musaphaga violacea*), and perhaps in traces in the blood of all these birds, turacin, and therefore copper, does occur. Still the whole mystery of this strange pigment is far from being understood.

3°. A word or two about a third animal pigment must suffice. In the black and dark feathers of some birds, in black human hair, and possibly in the skin of some mammals, a black pigment is found. It is a remarkably stable compound, resisting the action of such a powerful chemical agent as tolerably strong sulphuric acid. Sorby obtained 1 grain of it from 100 grains of the feathers of the rook (*Corvus pica*), and found it to contain the following average

[1] See, for further details, Church on Turacin, in the Philosophical Transactions of the Royal Society, 1869, pp. 627-636.

percentages of these four elements: carbon, 55.4; hydrogen, 4.25; nitrogen, 8.5; oxygen, 31.85. The chemical and physiological relationships of this *pigmentum nigrum* are at present unknown. It differs widely from albumen, though it may be a product of its decomposition.

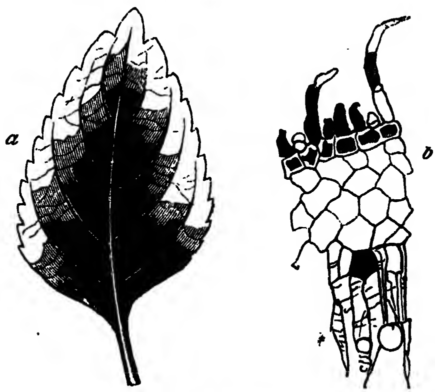
4°. Turning to the colouring matters of plants, leaf-green, or *chlorophyll*, in virtue both of its importance and abundance, claims the first place. Strange to say, however, in spite of the thousands of tons of this substance which are annually produced by grasses, herbs, and forest-trees, chemists have not yet ascertained its component elements, much less their relative proportions. We do not know whether it contains iron or nitrogen, although we are sure that it is never produced in the absence of compounds capable of supplying these elements. And further, it is possible that leaf-green may consist of more than one substance, or that the leaf-green of all plants may not be identical in every respect. Still some progress has been made in the study of this colouring matter, and a good many facts about it have been ascertained. It occurs, for instance, in all land plants having an independent existence—that is, not living upon other growing organisms, or on decaying organic matter. Chlorophyll, moreover, is found in those cells of plants where the absorption and decomposition of carbonic acid gas goes on, with which characteristic process of vegetable life it is closely concerned. Thus starch-granules are formed in such cells in the midst of a complex material to which the name of *protoplasm* is given, this protoplasm or formative substance being dyed, as it were, with chlorophyll. It is, then, extremely probable that chlorophyll, when under the influence of the sun's radiant energy, stands, in relation to the carbonic acid gas which plants decompose, very much in the same position of importance as hæmaglobin does to the gases of the blood.

One of the most characteristic properties of chlorophyll is the action of its solutions on light. The solar rays in part pass through the liquid, which appears green by such transmitted light. But in part they are reflected from its surface, and from some depth beneath, and become so changed thereby as to appear red. Thus a fresh solution of chlorophyll in ether is perfectly clear and green when you look *through* it,

but on being looked *at*, it seems to be full of minute particles of vermilion—it is an opaque red.

5°. It has long been known that many flowers, fruits, and even leaves, give to spirit of wine a colouring matter which is scarlet with acids, violet or purple in a neutral liquid, and blue or green in the presence of an alkaline substance like soda — dahlia-flowers, grape-skins, and red-cabbage leaves are examples. One colouring matter is probably common to all these plants and to many others. It has been called by many different names, but quite lately has been termed *colein*,[1] from *Coleus*, a genus of plants, in many species of which it occurs abundantly, both in stem and leaf. There is scarcely a doubt that it is closely allied to chlorophyll, but, unlike that pigment, it has no important office to fulfil in the plant. It is distributed in the most curious manner in the parts of the plants where it is found. In a leaf of *Coleus*, say *C. verschaffeltii*, it is irregularly distributed in the cells of

Fig. 88.



Coleus verschaffeltii.
a, Leaf, half natural size, showing distribution of colouring matter.
b, Hairs and epidermis of stem, magnified, showing cells containing colouring matter (colein).

the epidermis (*a*, fig. 88), some of these containing much, some a trace, and others none. But its mode of occurrence in the hairs of the stem and leaf is still more curious; a hair

[1] See Church on Colein, Journal Chem. Society, 1877, i. 253-262.

made up of, say, six cells, may have the end-cells richly tinted, and all the others free from colein. (See *b* in fig. 88.)

Colein is a red resinous-looking substance, which will not dissolve in ether, and but slightly in water, but is very soluble in spirit of wine. A weak alcoholic solution becomes nearly colourless after a few moments, but when it is poured on a porcelain plate it regains its colour as it dries up. With a drop of ammonia solution the colein becomes purple, violet, indigo, green, and then yellow; with a drop of acid it takes a scarlet hue. Colein has the percentage composition,—carbon, 57.7; hydrogen, 4.7; oxygen, 37.6. It is probably thus identical with the colouring matter of red wine, most red, blue, and purple flowers and fruits, and with the red pigment of the copper beech. Its solution forms a very sensitive test-paper for acids and alkalies.

6°. A third vegetable pigment, the chief colouring substance to which madder-root (*Rubia tinctorum*) owes its value as a dye, affords a most striking example of the methods and results of modern chemical research. After many long and tedious investigations as to the composition and relationships of this madder pigment, called *alizarin*, Graebe and Liebermann decided that its chemical composition was represented by the expression, $C_{14}\ H_8\ O_4$. These chemists further ascertained that it yielded a hydrocarbon (that is, a compound of carbon and hydrogen), having the formula $C_{14}\ H_{10}$, when distilled with zinc-dust and zinc-hydrate. Now this hydrocarbon, called *anthracene*, was already a well-known substance, which could be made from several chemical compounds, and occurred in considerable quantities in the less volatile parts of coal-tar. If alizarin, the red pigment derived from madder, gives anthracene, may not anthracene be made to give alizarin? The German chemists above named accomplished this transformation also. By a process which is essentially one of oxidation, two of hydrogen are taken away from anthracene, and four of oxygen added. This process, as improved by Perkin, consists in oxidising the anthracene by bichromate of potassium, heating the *anthraquinone* ($C_{14}\ H_8\ O_2$) formed with oil of vitriol, and then treating the last product with caustic potash. The materials being cheap, alizarin thus made has displaced the preparations from madder-root to a great extent, so that the growth and

imports of that valuable plant have greatly fallen off since this grand and almost unique discovery of how to prepare artificially a vegetable colouring matter. It is believed that the madder-root (much is grown at Avignon) used in this country in the three years following the discovery, chiefly for dyeing "Turkey red," is represented by the following values :—

1874, ...	£800,000
1875, ...	411,000
1876, ...	239,000

Strange that the heating of a few scarlet crystals with some powdered zinc in a test-tube should have produced so considerable an effect on commerce, destroying an old industry and creating many new ones. But the chemistry of the last thirty years has furnished many equal marvels, while the chemistry of the future promises to be still more fruitful. In this same matter of pigments scores of new and splendid dyes have been produced. Indigo, too, that old favourite, the prince of pigments, has at length revealed the secret of its structure to the questionings of the chemist, so that the elements of this colouring matter can now be put together without the assistance of the organic processes going on in the indigo-plant. But as yet the artifical building up of indigo is too costly and elaborate a process to be commercially available.

7°. With the coal-tar colours we are almost too familiar nowadays. Some of these colours in chief request are distressingly violent, and being often used unmixed and in masses fatigue the eye. The passing rainbow, set in a vast expanse of shaded grey, is pleasant and refreshing; but we should soon be wearied of a sky for ever filled with great arches of pure prismatic hues. But whatever the artistic and decorative failings of the coal-tar pigments as commonly employed may be, the chemistry of these brilliant and complex compounds is full of interest.

It was in the spring of 1856 that the first of the coal-tar dyes saw the light. Mr W. H. Perkin, then a young student of the College of Chemistry, during some experiments preparatory for an entirely different research, had occasion to attempt the oxidation of a liquid derived from coal-tar, and called *aniline*. Aniline (itself formerly made only, from

indigo) did not yield the expected product; but the spirit used with the object of extracting the wished-for new substance became of a superb purple hue. This was *mauve*, the forerunner of a countless host of new coloured substances, nearly all of which have been obtained from the following hydrocarbons present in coal-tar:—

Benzol, . .	C_6H_6	Naphthalene, . .	$C_{10}H_8$
Toluol, . .	C_7H_8	Anthracene, . .	$C_{14}H_{10}$

But carbolic acid, so familiar as a disinfectant, is likewise the source of several of these dyes. It is, however, not a hydrocarbon, though nearly related to benzol, and containing just one atom of oxygen in addition to the elements of that substance.

The chemistry of the coal-tar dyes is far too vast and intricate a subject to be discussed here; but there are three prominent aspects of the subject to which the reader's attention may be profitably directed.

a. The first of them is the material basis of these discoveries, and the process by which they have developed. How utterly unpromising is the appearance of the blackish-brown mess of offensive smell, the coal-tar, which is the prime source of mauve, magenta, magdala-red, corallin, aurin, &c.! But the chemist separates this tar into the several compounds of which it is a mixture. He studies these compounds individually—finds that some, like benzol, are colourless oily liquids; and others, like naphthalene, are crystalline solids. Then he learns their constitution, and what derivatives may be formed from them. He submits them to old methods and treatments; he devises new processes of torture. Finding one line of procedure yield a brown pigment with one compound, he repeats the experiment with a second compound and obtains a red product. A thousand failures do not daunt him. He aims at the discovery of nature's secrets by systematic questioning, and a scientific success often rewards him. He may secure that other success which every one can appreciate; but to enlarge the boundaries of science, not to fill a purse, has been the aim of the greatest discoverers.

b. A second point of interest exists in connection with the optical properties of many of the coal-tar pigments. A large number of them when in the solid state present that pecu-

liarly intense lustre known as metallic. Some reflect from their surfaces a hue like that of gold, others resemble bronze and copper. Another peculiarity is noticeable in a good many of these pigments, particularly amongst those derived from anthracene. Solutions of these coloured bodies are strongly fluorescent, changing some of the rays that fall upon them, and reflecting a yellow, green, or blue light of wonderful brilliancy. It is strange to see a crimson solution, perfectly transparent when looked *through*, so lighted up with an internal blue flame as to be dazzlingly opaque when looked *at*.

c. The third aspect of these dyes concerns their chemical constitution. They frequently present analogies and relationships amongst themselves, and these serve as guides to new discoveries. And we may even find that in some instances we can predict what hue a new product not yet made will have when its production has been realised. One instance of such predictions and relations must suffice. Rosaniline, the base of magenta, but itself colourless unless united with an acid, has in it three atoms of hydrogen which admit of being removed and replaced by certain *compound radicles*[1] as they are called—for instance, by methyl, ethyl, and phenyl. Put in one such radicle—say one of phenyl, and the new magenta has acquired a more purple hue: another phenyl gives a violet; the third produces a colour verging on blue. If then, generally, we want to give a bluer cast to any red colouring substance analogous to rosaniline in constitution, we have but to effect a smilar replacement to that just mentioned, and we may reasonably expect a similar result. To show how unexpected are the relationships which exist between some of these dyes the following case may be cited. A substance called *aurin*, of a golden red, is obtained from carbolic acid; its composition is probably expressed by $C_{19}\ H_{14}\ O_3$. Now one sort of rosaniline, made from toluol, is $C_{19}\ H_{17}\ N_3$; and it has been found that aurin long heated with ammonia yields rosaniline. This conversion has led chemists to a better knowledge of the constitution of both substances, and they are now regarded as bearing some such relation to one another as water bears to ammonia. It is difficult, perhaps impossible, to express such facts in untechnical language;

[1] See pp. 428 and 463.

but some notion of the relationship in question may be gathered from the mere inspection of these expressions—

3 of *water*,	$H_3\ (HO)_3$	3 of *ammonia*,	$H_3\ (NH_2)_3$
1 of *aurin*,	$C_{19}\ H_{11}\ (HO)_3$	1 of *rosaniline*,	$C_{19}\ H_{11}\ (NH_2)_3$

How rich and varied and beautiful—and, we may add, how important—is the whole science of colouring matters may be imagined from the glimpses we have here caught of the chlorophyll of the living leaf—the hæmaglobin of the active blood—the alizarin of madder and coal-tar. It is not a mere question of paints and dyes, but the thoughtful mind, no less than the educated eye, discovers a subject of delightful contemplation in "The Colours we Admire."

CHAPTER XXX.

WHAT WE BREATHE AND BREATHE FOR.

What is it to breathe ?—Structure of the lungs.—Quantity of air inhaled.—Tidal air and stationary air.—Effect of breathing on the composition of the air; it increases the proportions of moisture and carbonic acid gas, and diminishes that of oxygen; to what extent it does so.—Quantity of carbonic acid gas given off from the lungs and the skin.—Purpose for which man breathes.—The oxygen absorbed helps to form the substance of the muscular and other tissues; it converts the waste material of the body into urea and other soluble substances preparatory to its removal; it converts the fat and starch of the food into carbonic acid gas and water; acts in a similar way upon alcohol.—Why the carbonic acid from the lungs varies in quantity.—Physiological effect of these chemical changes; they are the chief source of animal heat.—Careful provision for the constant disengagement of this heat.—Purposes served in external nature by the breathing of animals.

I. What is it to Breathe?

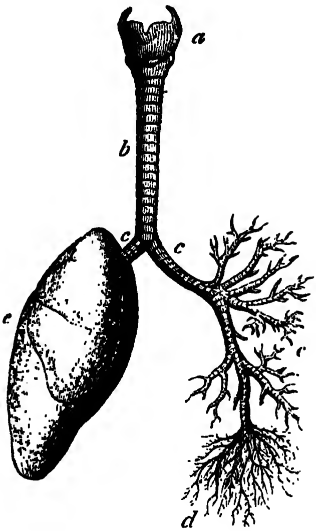
1°. To breathe, in the usual acceptation of the term, is to draw in atmospheric air through the mouth and nose into the lungs, and after a brief interval to throw it out again.

The lungs, into which the air is thus drawn, consist of two rounded oblong, somewhat flattened, masses of very cellular substance, situated in the cavity of the chest, and communicating with the atmosphere through the windpipe or trachea. The general form of the human lung is represented in the annexed figure.

The air or wind pipe (*a b*, fig. 89), as it descends from the throat, branches off into large (bronchial) tubes (*c c*); and these again and again into smaller, still smaller, and finally into hair-like vessels (*d*). Through these the air penetrates

into the remotest parts of the cellular substance. Around each *visible* extremity nearly 18,000 cells are clustered (17,790, ROUCHOUX), each of which is connected through these minute tubes with the external air. The cells vary in size; they have a diameter of from one-seventieth to one two-hundredth, or, on an average, of about one-hundredth of an inch. The total number of them is reckoned at 600,000,000! Their walls are very thin; they are mere air-vesicles.

Fig. 89.



Human Lung

a, The larynx; *b*, Windpipe; *c c c*, Bronchial tubes or air-passages; *d*, Hair-like vessels; *e*, Lung.

The lungs, as this structure implies, are very elastic, and consequently the volume of air they contain very variable. The average quantity which, by an effort, the lungs of an adult can be made to exhale or expire after the deepest inspiration possible, is rather more than 6½ pints; and the quantity they draw in at an ordinary, natural, but full inspiration, *may* be as much as 2½ pints: an ordinary tranquil respiration, made without effort, takes in only 1 pint.

At the easy average of 18 inspirations a-minute, this makes the bulk of air drawn in and thrown out again to amount—in common life—to about 18 pints a-minute, 1000 pints an hour, or 3000 gallons a-day. Some estimate it as high as 4000 gallons a-day for an average man in average circumstances, and as high as 5700 gallons a-day for an athletic man undergoing severe exertion. The air that enters the lung at an inspiration is called the *tidal* air, that which remains in it after an expiration is called the *stationary* air. The impurities of the latter diffuse them partly into the former at every breath.

But the breathing process is not wholly confined to the

lungs, both the intestinal canal and the skin being associated with the absorption of oxygen and the removal of the carbonic acid gas and water produced by oxidation.

Three distinct and sensible chemical alterations are produced by the breathing animal upon the air which enters and surrounds it.

First, If the breath of an animal, as it escapes from the mouth, be received in a dry cool vessel, or upon a clean mirror, the surface of either will be rendered dim by a thin coating of moisture. In like manner, if the naked hand or arm be enclosed in a clean dry glass vessel, a deposit of dew will gradually be formed upon its inner surface. Both from the lungs, therefore, and from the skin, watery vapour is continually, though insensibly, given off into the surrounding atmosphere. As it comes out, the air contains more moisture than when it went into the body. This is the first change.

Secondly, If the expired air from our lungs be passed through lime-water, it speedily renders the liquid milky (see p. 3).

Now, if we put a quantity of lime-water into a close bottle, and draw common atmospheric air through it, as in the annexed figure (fig. 90), we shall see that for a *long time* the water will remain bright and transparent. A very large volume of air must be drawn through before the clearness of the water sensibly diminishes, and still more before it becomes perceptibly milky. This shows that though carbonic acid is present in the air, it is so only in very small proportion.

Fig. 90.

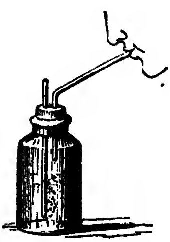


Fig. 91.

But if, instead of *drawing* atmospheric air through the lime-water, we *blow* through it the air which comes from the lungs, as in figure 91, we shall see the bright clearness of the liquor disappear almost immediately. In a very few minutes it will have become opaque and milky. The air, as it comes from the lungs, contains, therefore, more carbonic acid gas than as it went in. This is the second change.

In like manner, if any part of the naked body be surrounded

for a while by a close vessel, and the air within the vessel be subsequently examined, a slightly larger proportion of carbonic acid will be found in it than is usually present in an equal bulk of the surrounding atmosphere. Thus, from our lungs and from our skin, we are continually, though insensibly, breathing out carbonic acid, and adding to the proportion of this gas which naturally exists in the air in which we live.

Thirdly, If either the air which comes from our lungs, or that in which a naked limb has been for some time closely confined, be chemically examined, it will be found to contain a smaller percentage of oxygen than is present in common atmospheric air. The lungs, therefore, are continually drinking in oxygen from the air. This is the third change.

Thus the chemical alterations which atmospheric air undergoes through the agency of the breathing animal are,—that it is rendered moister than before—that the proportion of carbonic acid is increased—and that the percentage of oxygen is diminished.

2°. To what extent do these changes take place? Can we estimate it in numbers?

a. The quantity of water which is thrown out into the air from the lungs of a healthy man is very variable. It is modified by season and climate, by individual constitution and state of health, by the amount of exercise taken, by the quality of the food, by the quantity of liquid consumed, and by a variety of other circumstances. Generally speaking, however, the quantity given off from the lungs and skin together is equal to about one-third of the weight of the whole food, solid and liquid, which is taken into the stomach.

Now the skin alone of a full-grown man exhales in twenty-four hours, and in ordinary circumstances, from one and a half to two pounds of water in the state of insensible perspiration. The difference between this weight and that of one-third of the whole food, solid and liquid, represents the quantity of water daily discharged from the lungs. It is not far from the truth to say that, for every pound and a half discharged from the skin, about one pound is given off from the lungs.

b. We have already seen that the air we breathe contains, in its natural state and at ordinary elevations, about 4 gallons of carbonic acid gas in every 10,000 of air (p. 5). This is

its condition as it enters the lungs. As it returns it contains on an average 4 gallons in 100! In cases of disease the proportion of carbonic acid sometimes mounts up to as much as 7 gallons in 100. The quantity of this gas discharged from the lungs, therefore, in twenty-four hours, must be very considerable.

Like that of watery vapour, this quantity varies with many circumstances. Size, age, sex, food, climate, constitution, health, exercise, all modify it. A considerable difference results also from the amount of sunlight to which the human being is exposed, much less carbonic acid being given off in darkness than in daylight In a full-grown man the average weight of carbonic acid given off is rather more than 2 lb. in twenty-four hours.

This gas contains in every 100 lb. 28 lb. of carbon (pure charcoal) and 72 lb. of oxygen. Hence the average weight of carbon which escapes in this form from the lungs and skin of a full-grown man is nearly 9 ounces in the twenty-four hours. Of this only about 40 grains are given off by the skin.

c. The proportion of oxygen gas which atmospheric air contains is very nearly 21 gallons in every 100. After it has visited the human lungs, however, this proportion is reduced to 17 in 100, and is sometimes lower. The lungs extract from one-seventh to one-fifth of its oxygen. The absolute weight of the oxygen thus taken up in a day also varies with many circumstances. It is generally equal, in the case of an adult man, to about 1 lb. 10 oz., or one-fourth of the weight of his whole food, solid and liquid. But whatever increases the quantity of carbonic acid given off, generally increases, and nearly in an equal degree, that of the oxygen absorbed.

Such is this most vital process of respiration, considered in itself; and such is the chemical influence in kind and quantity which a full-grown man by his breathing insensibly exercises over the composition of the atmosphere which surrounds him.

But for what end does man breathe? What good follows to himself, or what useful purpose is served in external nature, by the changes which his breathing produces upon the air in which he lives? These questions we must consider in their order.

II. For what good to himself does man Breathe?

To obtain a clear answer to this question we must examine the function of respiration more closely.

The oxygen which enters into the circulation of the body through the lung-surface is equal in weight, as we have seen, to one-fourth of all the solids and liquids introduced into the stomach. It exceeds in weight that of the dry solid food taken alone. This oxygen is the main source of the good which man derives from breathing. This good is twofold. For the oxygen absorbed during breathing is the means by which that part of the food which has been digested, absorbed, and assimilated, is oxidised or burnt, thus keeping up, as in a steam-engine, the heat and activity of the body. And, secondly, the large bulk of air inhaled and then expired, carries away from the body the useless products of this burning, the carbonic acid gas and water vapour which we are continually pouring into the air.

We must now learn, in the next place, the nature of the substances thus burnt or oxidised in the body; then we must ascertain where this combustion takes place; and, lastly, we must discover what becomes of the products of combustion—how they are disposed of.

1°. As to the nature of the material which the oxygen of the air, taken into the lungs, combines with and burns, one fact is certain—it is combustible. Now the water and salts which we consume in our food are not combustible; while the starch, the sugar, the fat, the albumen, and other carbon-containing ingredients of our food, are combustible. To these latter compounds we must look for the fuel of the body.

2°. These substances, changed by digestion and absorbed into the circulating blood, which they continually renew, are burnt—that is, oxidised throughout the body. How much of the heat and mechanical energy of the body is derived from the direct burning of the substance of the muscles themselves, and how much from the burning of the combustible constituents ever present in the blood and juice of flesh, has not been determined. But that the oxygen of the air is carried into all parts of the circulation is known. It is carried chiefly in association or loose combination with the most important constituent of the blood. That constituent is a red substance,

hæmaglobin,[1] which forms the chief part of the *red corpuscles* of the blood.

3°. But if the carbon-containing substances derived from man's food are burnt throughout his body, and if this burning takes place because of oxygen brought from the lungs, how and in what forms, may we ask, are the products of this burning, being no longer of use, conveyed out of the body? The very *hæmaglobin* which has brought the oxygen carries away the chief product of the burning—namely, carbonic acid gas. The 8 or 9 ounces of water, too, which are daily produced by the burning of the hydrogen of the body-fuel, are also mainly removed in the return current of blood, and discharged from the lungs in the expired air. The waste of all the substances which contain carbon and hydrogen, but no nitrogen, is thus disposed of; but the nitrogenous compounds, which are also burned in the circulatory system, produce something else besides carbonic acid gas and water. The chief of these other products is called *urea*. Not being capable of passing away as vapour, it can only be removed from the blood in a liquid form. It is, in fact, a white crystalline substance, very soluble in water, and is discharged from the body daily, to the extent of about $1\frac{1}{3}$ ounce, in the urine. The blood secretes urine into the glandular organs called the kidneys just as it secretes sweat into the sweat-glands of the skin. Thus the solid waste of the nitrogen-compounds of the blood, left when the major part of their carbon and oxygen is burnt, is washed out of the blood, and leaves the body chiefly as urea. This urea contains in every 100 parts—

Nitrogen, ...	46.7
Carbon, ...	20.0
Hydrogen, ...	6.6
Oxygen, ...	26.7
	100.0

In other words, it contains just three times as much nitrogen as the compounds from which it was formed. These (albumen, fibrin, &c.) contain 15.8 parts of nitrogen in 100. Of these we burn or consume each day $4\frac{1}{4}$ ounce, from which are produced about $1\frac{1}{3}$ ounce of urea, with small quantities of other nitrogenous compounds, as uric acid.

[1] See the chapter on "The Colours we Admire."

I have stated in a previous part of this chapter that the absolute quantity of carbonic acid gas given off from the lungs is variable, and that the kind of food we at different times make use of is one of the causes of such variation. Even when the absolute quantity of oxygen drawn in from the air is the same, the quantity of carbonic acid gas returned to it may differ as much as three-tenths, or nearly one-third of the whole, supposing the food-substance with which the oxygen combines in the body to be at one time starch, and at another fat.

The indirect and physiological good.—But these chemical operations are attended by an indirect physiological effect which is essential to the existence of life.

From what has been stated above, it does not appear that any good purpose is served by the constant production in the blood-vessels and discharge from the lungs of carbonic acid gas and watery vapour. We can see the good which the oxygen does to the animal in forming the material of its tissues, and in subsequently removing the waste matter of these tissues as they wear away; but in the simple formation of carbonic acid and water we see none.

The good in this case arises, not from the mere chemical change itself, but from a certain physical circumstance that accompanies it.

It is known that animals differ in the amount of sensible warmth which they naturally exhibit. Some, like fishes, have a temperature very little higher than that of the medium in which they live: they are cold-blooded. Others, like man and most quadrupeds, are considerably warmer than the air which surrounds them: they are warm-blooded. The internal heat of a healthy man, for example, in temperate climates, is about 98½° Fahr. In hot climates, and when he is attacked by fever, it rises to 100° F., and upwards. The horse has an internal heat of 101° F., amphibious animals of about 101½° F., ruminating animals of 104° F., and birds of 106° F., while in reptiles the mean heat falls to about 80° F.

But an animal, the body of which is always warmer than the air or other medium in which it lives, must have a source of heat within itself independent of external nature.

And when we consider how much heat must be continually

radiating from the surface of a warm animal into the cooler air, how much is expended in converting into vapour the water which continually escapes from its skin in the form of insensible perspiration, and from its lungs in invisible steam —how much in warming up the food and air which enter cold into its stomach and lungs, and are discharged again at a temperature nearly equal to that of the body itself—and that this escape of heat is incessant, and in a degree uniform, —all these circumstances compel us to the conclusion that this internal source of heat must be both large and constant.

And cold-blooded animals like fish are still not quite cold; they need supplies of heat and of energy—of the power of doing work. They get this by burning their food-materials in the oxygen of the water: not the oxygen which is a part of the chemical compound water, but the oxygen *dissolved* in the water, which usually amounts to about one-eighth of a part by volume.

And this connection between the production of carbonic acid gas and that of heat is placed beyond all doubt when we attend to the physical circumstances by which the change of sugar, starch, albumen, and fat into carbonic acid and water are accompanied in the external air. If we burn one of these substances in the air, or in pure oxygen gas, it disappears, and is entirely transformed into carbonic acid gas and water. This is what takes place also within the body.

But in the air this change is accompanied by a disengagement of heat and light—or, if it take place very slowly, of heat alone, without any visible light. Within the body it must be the same. Heat must be given off continuously as the starch, sugar, and fat of the food are changed within the body into carbonic acid and water. In this we have the continuous natural source of animal heat. Without this supply of heat the body would soon become cold and stiff. The formation of carbonic acid and water, therefore, continually goes on; and when the food ceases to supply the materials, the body of the animal itself is burned away, so to speak, that the heat may still be kept up. And so a fat animal in good condition can subsist longer without food than a lean one.

The good purpose served by the production of carbonic acid and water within the body is now apparent: it keeps

the body warm, and supplies it continually with the power of doing both internal and external work.

It is received as universally true, that whenever a body unites chemically with oxygen, some heat is given off, or becomes sensible.

There is both in the substance burnt and in the oxygen with which it combines a certain amount of stored-up power or energy; and of this a part, differing in amount with different combustibles, and with the completeness of the combustion, is set free—*potential* energy becomes *actual.* Now one form of actual energy is heat—another form is manifested in work done. Work is done in breathing, in driving the blood through the body: work is done outside the body when it moves from place to place, or when the hand lifts a weight. If you can get heat out of anything, you can get work also, for heat and work are convertible. The same heat which will warm 1 lb. of water 1° Fahr., is equal to the task of raising a weight of 772 lb. to the height of 1 foot. That is *the mechanical equivalent of heat.* And we may therefore express the total heat producible by the complete burning of the chief combustible food-constituents, in the form of so many tons raised one foot high. Here is such a set of figures:—

By burning 1 lb. of	Tons are raised 1 foot high.
Starch,	2427
Grape-sugar,	2033
Oil,	5649
Gluten, albumen, or fibrin,	2643

From the last figure we must deduct one-seventh, for gluten, &c. cannot be burnt completely in the body. And we must not forget also that only one-fifth of the energy or power of doing work is available for work *outside* the body, the rest being used in *inside* work or as heat.

The continuous formation of carbonic acid gas and water within the body of the breathing animal arises, then, from the urgent necessity of a constant supply of heat and energy. And in it we find the explanation of two remarkable circumstances, in which, were man concerned, we should say that an anxious solicitude was manifest on the part of the contriver and adjuster.

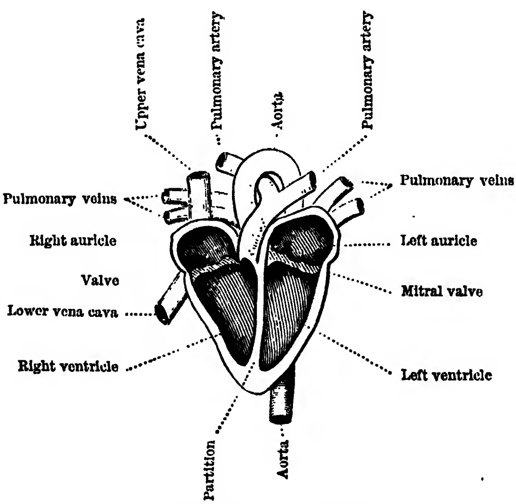
The first is the wonderful provision that is made within

the animal for bringing the whole blood into frequent communication with the oxygen of the atmosphere. This is seen in the structure and connection of the lungs and the heart.

The structure of the human lungs has been already described (p. 499), and it has been stated that they contain about 600 millions of cells, varying in diameter from the two-hundredth to the seventieth of an inch. The internal surfaces of all these cells form together an area of about 160 square yards of thin cell-wall! Over the whole of this surface minute blood-vessels branch out, so as almost entirely to cover it. And along these tiny vessels the blood is continually flowing, and, as it flows, absorbing through their walls the oxygen of the inspired air.

Then the heart is contrived and constructed to keep up this flow. The structure of the heart is shown in fig. 92.

Fig. 92.



Section of the Human Heart.

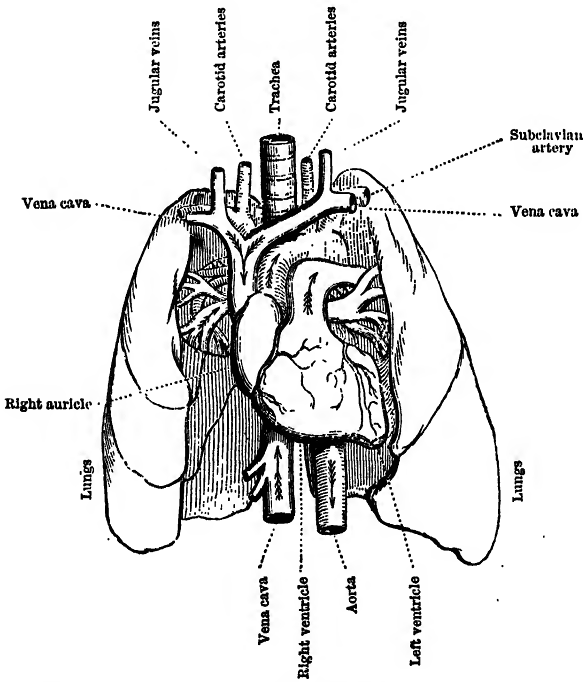
Returning from the extremities to the cavities here shown in the right side of the heart, the blood is thence driven into the lungs by a series of muscular contractions and expan-

sions, aided by valves opening one way. Returning from the lungs to the cavities on the left side, it is driven thence along the arteries, which convey it again to the most distant parts of the body.

The mutual adjustment and structural relations of the heart and lungs to each other will be better understood by an inspection of fig. 93.

This shows the situation of the heart between the two

Fig. 93.



Interior of the Lungs, showing their connection with the Heart and the large Blood-vessels.

lobes of the lungs. The double arrow in the upper vena cava, and the single arrow in the lower vena cava, show how the blood is conveyed through these two channels into the right auricle of the heart, and the arrow ascending from the

right ventricle, how the blood flows from it towards the lungs. The unshaded branching vessels which connect the lungs with the unseen left auricle carry back the blood from the lungs to the heart, while the ascending arrow between the upper vena cava and the right ventricle shows the course of the aorta through which the blood from the heart proceeds on its new journey towards the extremities.[1]

The weight of the entire blood of a full-grown man is about one-thirteenth of his weight, or 12 lb. in 154. Of this the lungs, in a state of health, contain about half a pound. The heart beats on an average 70 times a minute. Every beat sends forward 6 ounces of the fluid. It rushes on in the great arteries at the rate of 50 feet or more a minute, and a quantity of blood equal to the whole amount is calculated to pass through the lungs in less than half a minute!

How anxiously, if I may so speak, the oxidation of the blood is thus provided for!—first, by the large surface over which it is made to spread within the lungs; second, by the complicated machinery of the heart, which keeps it in motion; and third, by the extraordinary rapidity, and consequent frequency, with which it is compelled to flow over the wide lung-surface.

The second circumstance accounted for, is the large proportion of starch, sugar, or fat, which exists in nearly all the varieties of vegetable food on which we live. These, and especially the starch and sugar, are not required, as the gluten of bread and albumen and fibrin are, directly to build up the substance of the body. They are converted into carbonic acid gas and water in order that the heat and force of the animal may be kept up. They form in every kind of vegetable food, therefore, which in any part of the world serves as "the staff of human life," by far the largest portion of its weight. If it is carefully provided that oxygen shall never

[1] The blood, in circulating, comes from the extremities,—

1. To the venæ cavæ.
2. To the right auricle.
3. To the right ventricle.
4. To the pulmonary artery.
5. To the lungs.
6. To the pulmonary veins.
7. To the left auricle.
8. To the left ventricle.
9. To the aorta.
10. To the arteries.
11. To the capillary or hair-like vessels.
12. To the veins, which lead it all back to the venæ cavæ.

Through nearly the whole of these stages its course may be traced by the aid of the woodcuts in the text.

be wanting in the blood, equal care has been taken that the vegetable feeder shall always convey into its stomach those substances with which the oxygen can most usefully combine.

In the food of flesh-eating animals, fat serves the same purpose as starch does in that of the vegetable feeders; and in the relish for fat flesh which such animals display, we see a new provision for securing its introduction into their stomachs.

It is necessary to add to what has been said on this point, that though starch and sugar and fat are the substances which are generally converted into the carbonic acid we give off from our lungs, yet that we can live and breathe, though with less comfort, for some time without them. It is a further provision for the maintenance of human life, that in case of emergency the gluten of the plant and the fibrin of the animal flesh can be made not only to furnish fresh muscle but may be consumed as fuel like starch and fat, and may be converted within the body into carbonic acid and water, and in this form be discharged in our breath. Hence the strength-supporting virtues of the dried flesh, containing probably little fat, on which the bold riders of the Pampas are for the most part sustained.

It is interesting, as giving support to the view above explained in regard to the source of animal heat, that in certain cases a sensible warmth is produced in plants by a similar chemical change. The leaves of plants in general give off oxygen gas in the sunlight, and absorb carbonic acid gas. But to this law the parts or petals of flowers present an exception. They give off carbonic acid and absorb oxygen, as the lungs of animals do, and the flowers alone, and their appendages, of all the parts of a living plant are sensibly warmer than the air which surrounds them. In most cases they are only one, or one and a half degree warmer than the air, but in rare instances they become sensibly warm to the touch. This is the case with plants of the Arum family, in one of which—the *Arum cordifolium*—the flower has been observed to have a heat of 121° F., while that of the air was only 66° F.; and once at Kew, the air in the flower-spathe of a plant got so hot in this way as to expand and explode its sheath with a loud report! As in the animal, it is to the

union of the oxygen absorbed from the air with some starch-like ingredient in the sap of the flower-stalks and sheath, that the production of this warmth is to be ascribed. This is proved by the fact that the greater the quantity of oxygen absorbed by the flower, the higher the temperature it reaches —(GARREAU).

III. WHAT PURPOSE IN EXTERNAL NATURE IS SERVED BY THE BREATHING OF ANIMALS? Our consideration of this point need only be very brief.

The animal is not an independent part of the works or system of nature. Oxygen is not diffused through the atmosphere in nicely-adjusted proportions, solely that warm-blooded animals may breathe it; nor are the nicely-adjusted functions of life maintained within these animals solely for their own benefit. They breathe not less for the support of the vegetable kingdom than for their own.

We have already seen that the air which surrounds us contains about four ten-thousandths of its bulk of carbonic acid gas, and that all the green leaves which flourish on the face of the earth are ceaselessly, during daylight, sucking in from the air this thinly-diffused gas. In a very few years, working as they do now, existing plants would absorb the whole, were no new supplies poured into the atmosphere to make good the rapid loss. It has been calculated that an acre of beech-forest annually consumes 3½ tons of carbonic acid gas, or one-eighth of the total amount present at one time in the air above an acre of surface. The breathing of animals is one of the main sources from which fresh supplies come. The carbonic acid they pour continuously from their lungs and skin, while life lasts, takes the place of that which plants as unweariedly extract from it. And thus, while the circle of natural operations within the animal is complete in itself, and in every move it makes the animal seems to work only for its own good, it is all the while unconsciously labouring for the benefit of an entirely different order of existences external to itself. On its restless activity, it is true, its own life depends, but this life itself is only part of a larger circle of operations in which material things obediently revolve in the fulfilment of a greater purpose.

Thus the breathing of man has an internal and an external

end: within, it oxidises and warms the body, gives it energy and motion, and renews and purifies its parts; without, it contributes to the maintenance of the general system of animated nature. To man, as a mere living animal, the former end is the most immediately interesting and important; to man, as a philosophic observer of nature, the latter is not only the grander of the two, but the more morally and intellectually beautiful.

CHAPTER XXXI.

WHAT, HOW, AND WHY WE DIGEST.

What we digest.—Staple elements of food, whether animal or vegetable.—How we digest.—What takes place in the mouth.—The saliva; quantity discharged into the mouth; its composition and functions.—Properties of ptyalin.—The saliva is alkaline; always on the watch for the entrance of food into the stomach.—Structure of the alimentary canal.—The stomach and its appendages.—What takes place in the stomach.—The starch, fat, and gluten, are brought into a liquid state.—Dissolving action of the pepsin.—Absorption from the stomach itself.—What takes place below the stomach.—Introduction of liquids from the gall-bladder and pancreas.—Supposed action of the bile.—Properties and uses of the pancreatic juice.—Intestinal juice.—The universal solvent.—Absorption by the lacteals.—Changes of the chyle in the lacteals.—Mesenteric glands.—Absorption by the veins.—Digestion in the large intestines.—Acidity in the cœcum.—Final discharge of food-residues from the intestines.—Why we digest—it is to form blood.—Purposes served by the blood.—Composition of the whole man, and of his blood.—Bodily functions discharged through the aid of the blood.—Bodily waste and motion connected.—Special provisions for digestion in carnivorous and herbivorous races.—Digestion in the sheep.—Purpose of digestion the same in all animals.

WHAT we digest, how we digest, why we digest—how wide and interesting a field is embraced by these three topics!

I. WHAT WE DIGEST.—This topich as already been sufficiently dwelt upon in considering "The Bread we Eat," and "The Beef we Cook." Whether we sustain ourselves by means of vegetable or of animal food, we introduce nearly the same substances into the stomach. These different forms of food consist in the main, respectively—

The *bread*—of gluten, starch or fat, and saline matter.
The *beef*—of fibrin, fat, and saline matter.

And, as we have seen, gluten and fibrin on the one hand, and starch and fat on the other, serve similar purposes, and may take the place of each other almost indifferently in a nutritious food. These, therefore, along with the saline matters contained in both animal and vegetable food, are the main substances we digest. It is true that vegetable food contains also insoluble substances called cellulose or lignose—the materials of the cell-walls and vessels of plants. Speaking of these as woody fibre, for convenience' sake, we shall find that in the bran of the bread we eat, and in the green vegetables and potatoes we consume, it is present in notable quantity; and it forms a very large part of the hay and other dried vegetable food with which cattle are fed. This woody fibre, however, passes through the animal, for the most part, useless and undigested. The digestive organs extract, from among the useless materials which the food may contain, the three staple forms of matter above described. We have only to follow these substances into the body, therefore, and see what becomes of them.

II. How we Digest.—The process of digestion involves three successive series of operations, mechanical and chemical. The first of these takes place in the mouth, the second in the stomach, and the third in the intestines.

1°. *What takes place in the mouth.*—We have already seen that in ripe fruits and other kinds of vegetable food prepared by nature for immediate eating, the solid nutritious matter they contain is very minutely divided, and is intermixed with a large proportion of water. We have seen, also, that the first object of the cook, in a great number of our ordinary culinary operations, is to bring the raw food into the same minutely divided and highly diluted condition. But all the food we eat is not so prepared, either by nature or by art. The first operation we perform upon it, therefore, is to grind it, if necessary, by means of the teeth, and to dilute and season it by means of the warm, fluid, salt-containing saliva. It is then swallowed, and allowed to descend to the stomach.

This operation appears to be altogether mechanical; and yet the chemical history of the saliva, which takes so great a part in the operation, and the relations of this saliva to the food, are both interesting and important. The saliva is

secreted in glands which open into the interior of the mouth (fig. 94), and which, in some animals, are of large size. The quantity of liquid which these glands discharge into the mouth, and thence into the stomach, is very variable. In the case of the full-grown man it is sometimes as low as 8 and sometimes as high as 21 ounces in the twenty-four hours. According to some authorities as much as 70 ounces may be formed.

The saliva consists for the most part of water, and therefore, as I have said, its first function is to dilute the solid food. But this water holds in solution about half a per cent of organic and saline matter. In the 21 ounces sometimes swallowed in a day, there are about 20 grains of this saline matter. But this saline matter, half of which is chlorides, is accompanied by a peculiar organic matter, an unorganised ferment, to which, from its occurring only in the saliva, the name of *ptyalin* is given. Like the diastase described in a previous chapter, ptyalin possesses the property of changing the starch of the food into sugar. This property it exhibits in perfection, when the starch is dissolved or cooked, and when the temperature of the liquid approaches 98° F., when used alone—according to others, only when mixed with the saline constituents of the saliva. It forms less than one five-hundredth part of the whole weight of the saliva. Not more, therefore, than a few grains of it are swallowed by a healthy man in the twenty-four hours; yet this small quantity is really of much consequence to the easy and comfortable digestion of the food. Hence it is that experience has recommended to all good livers a careful mastication of their food, that all parts of it may be thoroughly mixed with the saliva, and thus subjected to its chemical action.

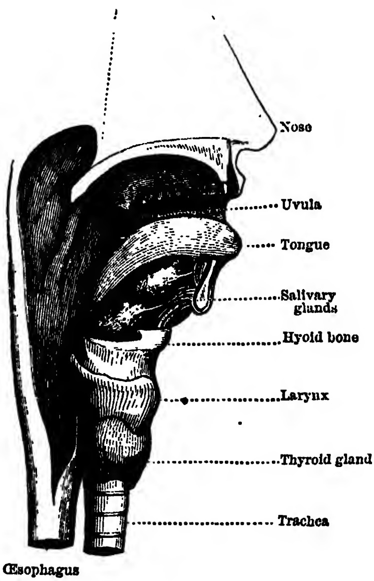
Two other facts regarding the saliva are of much interest as wonders of the human frame, independent altogether of their intimate relation to the process of digestion. One of these is, that the saliva has generally an alkaline[1] character—that this *alkalinity* is greater during and immediately after eating, and gradually lessens, till after long fasting the

[1] Substances are *alkaline* which have the taste of pearl-ash or common soda, or which restore the colour of vegetable blues that have been reddened by an acid.

saliva becomes acid—that it is greater, also, after substances have been eaten which are difficult of digestion—and that, when the saliva discharged into the mouth is spat out instead of being swallowed, acidity and heartburn often ensue—(WRIGHT). These circumstances argue not only a close connection between the process of digestion and the alkaline character of the saliva, but an immediate watchfulness, as it were, over the immediate wants of a particular bodily organ.

The other fact is, that as soon as food is swallowed, the saliva begins to flow more copiously than before. This is the case even if the food be swallowed without chewing. Or if food be introduced by an artificial opening into the stomach, without passing through the mouth at all, the saliva will forthwith begin to discharge itself into the mouth, with its alkaline character, and hasten down the throat to assist in the digestion. It appears strictly correct to say that the saliva is constantly on the watch to be useful, when we recollect how the mouth will often "water" at the mere mention of savoury articles of diet.

Fig. 94.



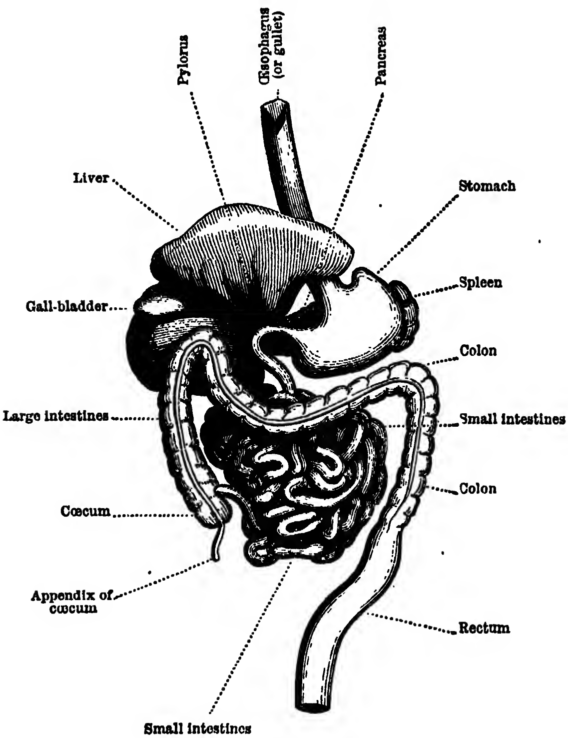
When chewed and duly thinned with saliva, and, from the ropy character of the latter, mingled with a certain quantity of air, and therefore of oxygen, the food is rolled by the tongue, and is swallowed or forced down the gullet or œsophagus on its way to the stomach. The annexed fig., 94, shows the gullet cut open, and its position behind the trachea or windpipe.

The figure shows also the position of two of the salivary sacs or glands which lie beneath the tongue, and from which

the saliva flows into the mouth when food is introduced into it.

2°. *What takes place in the stomach.*—The stomach, into which the food descends through the gullet, is an oblong rounded bag, capable, when moderately distended, of containing two or three pints. The annexed fig., 95, shows

Fig. 95.



the form of the human stomach, and of the neighbouring organs which are concerned in the process of digestion. It exhibits, also, their relative positions and their comparative sizes. The parts, as here shown, are a little distorted, from the necessity of turning up the liver in order that the gall-

bladder, the pancreas, and the upper part of the intestines might be more distinctly seen.

The food after it reaches the stomach is mixed up with more water if it has not been already sufficiently diluted. It is intermingled, at the same time, with certain liquids which flow out of minute openings on the inner surface—the mucous membrane, as it is called—of the stomach. And after these admixtures, it is digested for an indefinite period, at a constant temperature of about 98½° F.

But during this digestion it undergoes certain chemical and mechanical changes. Thus—

First, The *starch*, through the continued agency of the saliva, and especially of the ptyalin it contains, is gradually converted for the most part into the variety of sugar called *glucose* or grape-sugar. It then dissolves, and is ready to be conveyed towards its further destination.[1]

Secondly, The *fat*, without undergoing any known chemical change, is subdivided into exceedingly minute globules, and is intermingled intimately with the other half-fluid portions of the food. With these it forms in this way a kind of emulsion, and is then also ready to pass on.

Thirdly, The *gluten and fibrin*, and similar nitrogenous nutrients, which are solid when swallowed, are also reduced in the stomach to the fluid form. But this is effected by means of a new agency.

Within the mucous membrane which lines the interior of the stomach, many little cavities or hollows are situated. From the surfaces of some of these, a liquid, which is known by the name of the gastric juice, flows into the stomach. This liquid contains saline matter, a quantity of free acid which renders it slightly sour, and a peculiar organic substance to which the name of *pepsin* has been given. This last substance is present in the gastric juice only in minute proportion. Like the ptyalin of the saliva, however, it exercises a powerful and important action upon the food. While

[1] The saliva of some animals appears to be much more powerfully solvent than that of man; in some cases it is even acid instead of alkaline. It may be safely assumed that its function is not always to dissolve starch, but it may even have the power of dissolving limestone, like the saliva of a Mediterranean shell-fish, *Dolium golea*, which contains both hydrochloric and sulphuric acid.

the ptyalin changes the starch, first into sugar, and afterwards partially into lactic acid, the pepsin, with the aid of the free acid, reduces the fibrin of flesh to the liquid state. The curd of milk and the white of egg are also readily changed by the gastric juice into soluble forms. Upon gelatinous substances it exercises a speedily dissolving action; and upon the gluten of wheat, though a little more slow, its final effect is the same. These dissolved albumens, fibrins, and caseins are, however, not merely dissolved; they are so altered by the pepsin ferment and the acid that they can pass through membranes and cell-walls which before they could not do. They are now called *peptones*. Of the gastric juice as much as 60 to 80 ounces are supposed to be poured into the stomach of a well-fed grown man every twenty-four hours.

Thus, by the conjoined chemical agency of the saliva and the gastric juice — aided by the uniform warmth of the stomach—the fat, the starch, and the gluten of the food are all brought into a half-fluid state. The saline matter of the food is in part changed and dissolved by the same agencies. The whole forms a greyish, gruel-like, slightly acid food-pulp, which has been called chyme.

This chyme now flows through the narrow outlet from the stomach—the pylorus (see fig. 95)—into the upper part of the small intestines, which, from its length of twelve inches, has been called the duodenum.

All the food, however, which enters the stomach does not thus linger in the stomach itself, or thus pass downwards through the pylorus.

What we swallow in the liquid state — our gruels and gravy-soups, for example—requires no dissolution or breaking down in the stomach, though they experience the other changes named—starch being in part turned into sugar, and albumen, &c., into peptones. They pass on, therefore, with little delay, and for the most part descend through the pylorus into the duodenum in a comparatively short period of time.

And again, from the moment that our solid food begins to dissolve in the stomach, it begins also to be absorbed through the sides of the stomach itself. Minute blood-vessels spread over the whole internal surface of the stomach, drink in liquid parts of the food through their thin walls, and carry

them away to be mingled with the general blood. Thus, a variable proportion of the food never reaches the pylorus, or descends into the duodenum. Thus, also, the process of nourishment begins almost as soon as the food is introduced into the stomach. The strength is kept up by one part of it, while the rest is undergoing the necessary processes of chemical preparation.

3°. *What takes place after it leaves the stomach.*—A glance at the woodcut (fig. 95) shows a small vessel or tube proceeding from the gall-bladder, and entering the duodenum a little below the pylorus, or outlet of the stomach. Another vessel, not seen in the figure, comes in from the pancreas or sweetbread. The former pours bile into the intestine; the latter, a thin saliva-like liquid, called the pancreatic juice. At the same time, from the surface of the intestine itself, a peculiar half-liquid slimy mucus exudes, which is called the intestinal juice (*succus entericus*). With these three liquids the food-pulp or chyme almost immediately mixes as it passes onward from the stomach. When so mixed it loses its acid character, some (often all) of the starch still unchanged is here converted into sugar, and the albumens into peptones, and it becomes milky in appearance. It is now changed into chyle.

The first chemical effect of the bile is to remove the acidity of the food-pulp. Its subsequent action is not well understood, but its presence is known to be necessary to healthy and nutritious digestion. It restrains the tendency of the food to fermentation, and to that form of decay, or decomposition, which is indicated by flatulence and the occurrence of diarrhœa. It also provokes the surface of the intestines to discharge more copiously the intestinal juice, and it tends to keep the bowels in movement.

The pancreatic juice resembles the saliva very much in appearance. Like the saliva, also, it contains saline matter, and a peculiar organic compound, which, however, is different from the ptyalin of saliva. In common with ptyalin, this compound body possesses the property of converting starch into sugar, and thus continues in the bowels the transformation of the starch which the ptyalin had begun in the stomach. It exercises a peculiar action, however, upon the fat of the food, reducing it to a more minute state of division than before,

converting it into a more perfect emulsion (a property it shares with the bile), and giving to the chyle its characteristic milky appearance. Its special duty is believed to be to promote the digestion of oily and fatty food.

The intestinal juice aids the action of the fluid of the pancreas. It has the property of changing starch into sugar, and at least assists in emulsifying the fat.

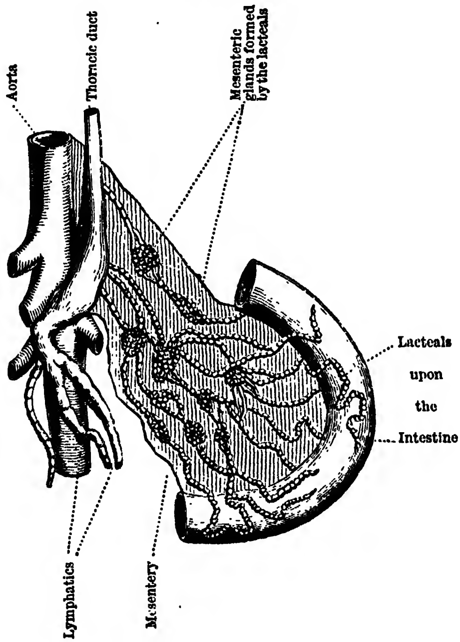
This latter action is inferred from the fact, that the solution of the whole food is much more complete and rapid when it is mixed with all these fluids in succession, or to some extent together, than when treated with one of them only. They complete the chemical action of each other, so that the resultant action of the saliva, the gastric juice, the intestinal juice, the bile, and the pancreatic fluid, is that of a kind of "universal solvent," by which all that the food contains of a nutritious quality is melted together, as it were, and fitted to enter the absorbent vessels.

And now the chyle being formed, a new variety of absorption begins. While within the stomach, the fatty portions of the food were still too little reduced to admit of their being taken up in suitable quantity by the absorbent vessels. The liquid which these took up was the watery lymph. But the fats broken up by the bile and the pancreatic juice are absorbed by what are called the *villi* of the intestines, and pass into the *lacteal* vessels. These gather a milky fluid. Throughout the whole of the smaller intestines, the same operation goes on. The intestinal juice is continually poured out and mixed with the food as it descends. It is more and more digested and exhausted of its nutritious matter, and lacteals continue to convey from it, at every point in its descent, fresh supplies of the milky chyle.

On its way through the lacteals, the chyle undergoes further chemical changes. To promote these changes it is detained here and there by being obliged to pass through several knots or glands, where many of the lacteals meet together, and intermingle their contents. Finally, all the lacteals terminate in the thoracic duct (fig. 96)—a vessel which in man is about as large as a goose-quill—and by this duct the chyle is conveyed into the jugular vein. Thence it is forced forward to the lungs, where it assumes a red colour, and contributes continually to the formation of new blood.

The following fig., 96, shows how the lacteals are distributed upon the intestine,—how they subsequently collect

Fig. 96.



together in glands or knots, as they pass along the mesentery or membrane to which the intestines are attached, and how they finally terminate in the thoracic duct.

But besides this absorption of the milky fluid, called chyle, which is conveyed to the blood-vessels by the lacteals above described continuously from the internal surface of the intestinal canal, another fluid, to which the name of lymph is given, is also absorbed. Lymph is taken up in minute vessels, which abound in the viscera, and occur to a small extent in the muscular flesh. The lymph in these lymphatic vessels, absorbed from the surrounding juices, passes like the absorbed chyle in the lacteals to the thoracic duct. In this way nourishing materials, partly of a different kind from those

which flow along the lacteals, mingle with the rest of the blood, are conveyed to the heart, and are finally employed for the support of the living body. But the lymphatics carry some waste or half-waste matter with them, so that their contents are not wholly nutritive.

What is the chemical nature of the substances which are thus taken up by the minute absorbent vessels, or what proportion they bear to the quantity of nutritive matter carried off by the lacteals—in regard to both these points we are yet in the dark. All that enters the veins in this way is immediately mixed with the blood, which the veins are bringing back from the extremities. Hence it is very difficult to make out satisfactorily what portion of the constituents of this blood is drawn from the food contained in the intestinal canal. That the quantity, however, is large, and its nature important to the health of the animal, there is every reason to believe.

When the food has passed through the small intestines and reached the cœcum (see fig. 95), the nutritious matter it contains is nearly exhausted in consequence of the different forms of absorption above described. In the colon digestion and absorption do occur, for life may be sustained by food injected therein. A change has taken place, however, in the chemical character of its contents. When the food-pulp escaped from the stomach, it was slightly acid. The admixture of the bile and the other alkaline secretions render it alkaline at about half-way down the smaller intestines. But in the cœcum it becomes slightly acid again, chiefly from the presence of lactic acid and fatty acids due to fermentation and the decomposition of fats. The residual food is detained there for some time, that it may undergo a final digestion before its useless residue is altogether discharged from the bowels.

Such is a sketch of the process of digestion,—of the way in which it takes place—of the complicated apparatus and organs which take part in it—and of the chemical agents which are specially prepared and always ready to assist in it. One long preliminary cooking process goes on from the mouth downwards all the way to the colon, and from every part of this long canal tiny lacteals and absorbing veinlets carry off contributions of cooked food either to the general

store of chyle, which is collected in the thoracic duct, or to the venous blood which is hurrying back to the heart. How effectual all this digestion is in exhausting what we eat of its nutritive matter, may be judged of from the fact, that a healthy grown man, fed with ordinary diet, rejects in his solid excreta only about 300 grains of carbon out of the 4900 grains which he daily consumes in his food, so perfect are the processes of assimilation and combustion which go on in the body!

III. WHY WE DIGEST.—This question is, in a certain restricted sense, already answered by the preceding statements. We digest our food that we may prepare materials for the production of blood.

Of what substances, then, does this blood itself consist?

If 100 lb. of human blood be rendered perfectly dry, by a heat not much exceeding that of boiling water, it will be reduced in weight to somewhat less than 22 lb. It loses about 78¾ per cent of water.

This dry matter consists mainly of the colouring matter called *hæmaglobin*, of albumen, and related substances. It contains a little sugar and fat, and about ¾ of a per cent of saline matter, made up of chlorides, phosphates, and sulphates. As blood is so rich in nitrogenous matter, which forms one-fifth of its weight, lean flesh is better adapted for its formation than most kinds of vegetable food.

The composition of the blood varies slightly with the age, sex, constitution, state of health, &c., of the individual.

We digest our food that blood may be formed from it. This answer does not go far enough in explaining the purpose served by digestion. The blood being formed as the result of the processes above described, what purpose does *it* serve? An explanation of this purpose will give the true answer to the question, Why we digest?

The blood serves a double purpose. *First*, it supplies the materials which are necessary to build up and to repair the several parts of the body; *secondly*, it enables the body, without final loss of substance, to discharge the functions on which its life depends.

First, It builds up and repairs the body. To understand this part of its office, it is only necessary to consider of what substances the body and blood respectively consist.

We have already seen that both animals and plants consist for the most part of water. A model man, weighing 154 lb., may be roughly estimated to consist of—

Water, ...	109 lb.
Dry matter, ...	45[1] ,,

And this dry matter consists of—

Organic or combustible matter, chiefly in flesh, fat, skin, brain,	34 lb.
Mineral or incombustible matter of bone, &c.,	11 ,,

The proportion which the fat bears to the dried flesh varies in different individuals, and in the case of man has seldom been experimentally determined: it is said to amount to 4 or 5 lb. in a vigorous adult man of 11 stone. The fibrin, albumen and allied nitrogen compounds, will probably equal 29 lb.

Now the blood which is to sustain the substance of the body is itself included in the above general composition of the whole man. This blood weighs, in the liquid state, nearly 12 lb. in a healthy full-grown average man; and it contains but a few ounces of fat and mineral matter, with about 2 lb. of albumen, fibrin, and allied substances.

Thus it is clear that the blood present at any one time in the body would require to be many times renewed before it could renew or rebuild the whole of the muscle, fat, and bone of the body.

It will strike the reader who compares the absolute quantity of dry matter contained in the blood with that which forms the body, how very small a store of food the animal carries within itself. The blood contains by weight only one-fourteenth of the dry matter of the body, so that the strength of the latter could be sustained only for a very short period without supplies from other sources.

And yet, though the strength must fail, it is remarkable how long life will cling to the wasting body. An animal does not die of starvation till it has lost 40 per cent of its weight, and more than a third of its heat. The lamp of

[1] How small a quantity of solid matter is consistent with life in a grown man, may be judged of from the case of a stepmother ill-using and starving a boy of ten years of age till he weighed only 25 lb.! He was in appearance merely skin and bone. Supposing him to be only two-thirds water instead of three-fourths, the solid matter in his living body would be only about 8 lb.!

life continues slowly and faintly to burn. It expires at last, partly from the failure of fuel, and partly from the stoppage of the circulation by the increasing coldness of the extremities. But—

Secondly, The blood enables the body, without final loss of substance, to discharge those functions on which its life depends. And it is in considering how much is implied in this duty of the blood, that the necessity of constant and large supplies of food from without becomes most apparent.

While man lives he breathes and moves. What demand for nutritive matter does the exhibition of these characteristic appearances of life involve?

In the preceding chapter we have seen that the animal eats a large portion of food in order that it may combine it with the oxygen taken in by the lungs, and then breathe it away again in the form of carbonic acid and water. But before it can be so combined with oxygen, it must be digested and conveyed into the blood. Thus it may be said with truth, that *we digest in order that we may breathe.*

And as this breathing is continually going on, the blood must as constantly supply the materials out of which the carbonic acid and water may be produced. But that it may do so without lessening its own substance, new streams of chyle must be ever flowing into it, and new food digested, that this chyle may be formed. Hence the necessity and use of that large quantity of starch or fat which a full-grown man must daily eat if he is to continue to breathe, and yet retain the weight of his body undiminished.

Again, the living man moves. Look at him externally, and he is never wholly at rest. Internally, could we look at him, he is everywhere and always in motion. Even when sunk in sleep, there is scarcely an organ of his body which, if not moving itself, is not the seat of incessant motion. Now it is believed that every movement of the body—every stirring of a limb—every change, for example, in the position of my fingers as I write—every involuntary beating of my heart—every thought that passes through my brain—is accompanied by a change of matter greater or less in quantity at the particular spot where the movement takes place. A portion of the substance of the muscle, of the bone, of the

brain, of the juice of flesh, of the constituents of the blood itself, becomes chemically changed—oxidised—unfit, therefore, for the position it previously occupied as a part of the perfect body. All this altered or waste matter is continually undergoing removal through the veins, and its place is as continually supplied by new matter extracted from the arterial blood.

That all bodily movement is attended by waste of the bodily substance is a received opinion. An animal, when fasting, will lose from a fourteenth to a twelfth of its whole weight in twenty-four hours. This loss does not fall altogether upon the fat, but extends also in part to the tissues and general substance of the body. It is so great that the whole blood is unable altogether to replace it.

But even when an animal is fully fed, so that it can discharge the requisite quantity of carbonic acid from its lungs without in any way feeding upon itself, still, as I have said, a waste and renewal of the tissues and substance of the body everywhere goes on. It matters not whether this waste is a consequence of the perpetual movement of its parts, or arises from some other cause. It is known to proceed so rapidly that, supposing it all to fall on the actual substance of the body, it would involve its renewal in an average period of thirty days! Of course the rapidity of the general change of substance varies with the individual, his habits, his food, and his employment. The several parts of the body, also, will waste with different degrees of rapidity. If the amount of movement or labour performed by each part, for example, be the measure of the degree of waste—then, where much thinking is done, the brain will be more speedily renewed—where much bodily toil is undergone, the muscles called into action by the kind of toil will be oftenest changed and rebuilt—and where listless indolence and inactivity possess both body and mind, muscles and nerves alike will partake of a correspondingly slow change of substance.

Thus it may be said again, and with equal truth, that *man digests in order that he may move;* or he digests that he may repair the constant waste which is ascribed to the restlessness of the material particles which compose his ever-moving body. This waste the blood makes up; and the process of internal cooking must be continually going on, in order that

the blood may be able to discharge this duty without causing any permanent loss of substance to the body itself.

The questions we proposed to ourselves at the commencement of the present chapter are now answered.

What we digest consists essentially of the starch, fat, sugar, albumen, gluten, and mineral matter, which, as we have seen in a previous chapter, all varieties of nutritious food contain in greater or less proportion.

As to how we digest, it is through the united agency of the warmth of the body—of a curiously-constructed alimentary canal and its appended organs—and of various chemical substances poured into the food from the sides of this canal and from its subsidiary organs.

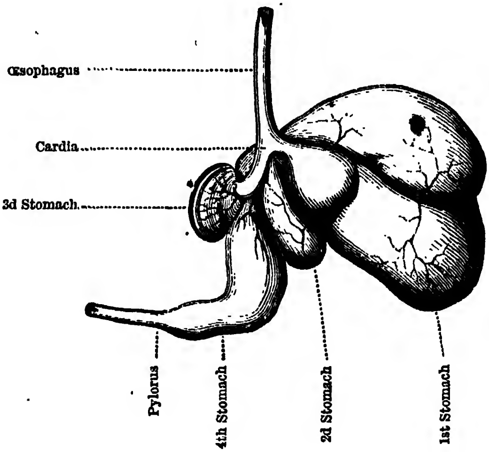
And the purpose for which we digest is, more immediately, to pour into the thoracic duct and absorbent veins the materials for the production of blood; but, more remotely, to build up the full-grown living man, and to enable him to breathe, move, and perform all the functions necessary to life, without sensible or permanent loss of his own substance.[1]

These three most interesting questions I have answered with special reference to the constitutional history of man. Were they asked in reference to other races of animals, the answers to the first two would be somewhat different. In fact, the nature of the food—of the thing to be digested—determines the form of the apparatus in which the digestion takes place, and also, in some degree, the chemical substances by which it is promoted. Thus in the carnivorous races—living upon flesh, which is more easily converted into chyle—the stomach is small, and the alimentary canal comparatively short. In the lion, for example, the stomach is small and narrow, almost a canal, and the intestines only three times the length of the body. In man, again, using as he does, a mixed food, the stomach is single but large, and the intestines seven or eight times the length of the body. But in herbivorous animals the canal is long, and the stomach not only large, but sometimes complicated in structure. In such as ruminate, or chew the cud, this is particularly the case, as may be seen in the following figure, which represents the fourfold

[1] A more complete account than could be included here of the whole process and results of digestion will be found in the late G. H. Lewes's Physiology of Common Life, i. 190-238.

stomach of the sheep. In the case of this animal, the food which is cropped or swallowed hastily passes unchewed into the large first stomach or paunch. Here it is moistened with a fluid admixture, and when required, is passed on to the

Fig. 97.



second stomach, and thence back to the mouth to be masticated. When chewed it is swallowed again, and proceeds at once to the third stomach or many-plies, and thence forward to the fourth stomach or reed, where the true gastric juice is mixed with it. From this latter it passes, as in man, through the pylorus into the intestines, which are twenty-eight times longer than its body. In the ox, the stomach is not only complex, as in the sheep, but the intestines are forty-eight times the length of the body.

The reason of all this complication in the digestive apparatus of the ruminating animal, is the difficulty of grinding down, and then of extracting, the whole of the nutritive matter from the kind of vegetable food on which the animal lives. Hence the food is longer detained in the alimentary canal, and is subjected to a more thorough process of subdivision and exhaustion, before it is allowed to escape from the body.

The chemistry of comparative digestion is indeed rich in interest and instruction; and, did my space permit, it were

easy to multiply illustrations of the way in which the instruments and means of digestion are adapted in every animal to the circumstances in which it is placed, to its habits of life, and to the chemical nature as well as the bulk of the food it is intended to consume.

In all animals, however, the end or purpose of digestion is the same,—to provide materials for building up its body to a full size, and afterwards for enabling it to discharge its various living functions, without permanent loss of its own weight or substance.

CHAPTER XXXII.

THE BODY WE CHERISH.

The body and its habits an assemblage of chemical wonders.—Change of the the food in its passage from the mouth to the lacteals.—Globules or corpuscles of the chyle.—The blood-corpuscles; their form and composition. —Mineral matter within and without the corpuscles.—The corpuscle is an independent microcosm.—Selecting power of the parts of the body.—How the whole system is kept in working order.—Activity of the vessels which remove waste matter.—Provisions for comfortable warmth.—Craving for special kinds of food.—How this is artificially met.—The nature of the water we drink may modify natural cravings and national diet.—Instinctive choice of beverages and condiments.—Case of salt; how instinct regulates the use of this substance.—Examples in South-western Africa and in Siberia.—Susceptibility of the body to the action of very minute portions of matter.—The narcotics, the beverages, the odours, and the miasms.—Influence of light upon the body.—The structure, functions, and special composition of the grey and white parts of the brain.—The *rete mucosum.* —The chemistry of all parts of the body deserving of intelligent and reverential study.

Nearly all the functions and habits, natural and acquired, the chemical history of which has formed the subject of the preceding chapters, have a relation more or less direct with the welfare and comfort of the body. Besides ministering to its necessary wants, we nourish and fondly cherish it. And in attempting to pleasure and pamper, we often injure it. This arises from our possessing, for the most part, too imperfect a knowledge of its vital wants and functions. We are too little familiar, also, with the substances we daily use or occasionally indulge in, or with which, in external nature, we cannot avoid coming into contact. And with this ignorance

of the things themselves, is necessarily associated a similar ignorance of the effects they are likely to produce upon the system.

This want of knowledge is by no means surprising, seeing that the whole grown-up man—the body and its habits together—may be described as an assemblage of chemical wonders. Besides the main features in his chemical history which have been already illustrated, there are a thousand others of a less general kind, the study of which is not only rich in the discovery of wise contrivances, so to speak, but is pregnant also with practical instruction. To some of these minor points I propose to devote the present chapter.

We have already seen how many curious circumstances attend the food in its progress from the mouth to the blood-vessels. The teeth grind it fine, and the tongue mixes it with saliva. This saliva, on the watch to be useful, rushes out and makes the mouth water whenever savoury food is spoken or even thought of. It flows most copiously, however, while we chew and while we are digesting. In doing so, the saliva not only moistens the food, but mixes up with it the substance *ptyalin*, which converts its starch into sugar, and is essential to the healthy progress of digestion. Then from the coats of the stomach exudes the gastric juice—also most copiously when there is most work to do. This fluid brings with it the peculiar substance *pepsin*, which renders soluble the gluten of wheat and the fibrin of flesh in the food. When this solution is accomplished, the gastric juice ceases to flow, and the liquid food moves forward to the smaller intestines. Here the sour chyme is mixed with three fluids, which are waiting its approach. A valve opens, and the bile comes out to meet the food—a juice flows forward from the pancreas, like a new saliva—and from the surface of the intestines, as it passes along, a third liquid issues to temper and chemically change it. The chyle, now milky and alkaline, is taken up by the lacteals. These minute vessels are distributed along the whole course of the intestines, extracting, at every step in its progress, new portions or constituents from the food, mixing them all together as the vessels meet in the glandular knots, and pouring the mixture into the one common reservoir—the thoracic duct. And to insure a thorough extraction of all feeding matter, a new change takes place when the food

descends into the larger intestine. It becomes acid again, and delivers to the still busy lacteals new materials with which to give the final tempering to the milky chyle as it flows towards the true blood-vessels.

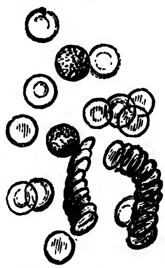
All this has been explained. But it will amply repay us if we follow a little further the chemistry of this incipient blood.

Seen under the microscope, the milky contents of the thoracic duct have very much the appearance of blood. Numberless rounded discs present themselves, which, by their peculiar granulated appearance, are recognised as the colourless corpuscles which characterise the blood (fig. 98 *b*). As soon

Fig. 98.

Fig. 99.

Fig. 100.



98. "The human red corpuscle, showing its natural form and appearance when brought fully into focus, in which case the centre always appears light. Scattered over the field are seen one or two white corpuscles (*b*)."
99. "The same seen united into rolls, as of miniature money in appearance."
100. "The blood-corpuscles of the elephant, red and white, which are the largest hitherto discovered among the Mammalia." All magnified 670 times.—(From Hassall's Microscopic Anatomy.)

as these enter the veins, however, and are thence driven over the lungs, they become coloured. By some chemical action in the lungs, they are made to assume a red colour, and are no longer distinguishable from the true red corpuscles of the blood.

Digestion may now be said to be completed, and true blood is formed. This blood is itself a most interesting study. Under the microscope the blood of man and other mammiferous animals is seen to consist of minute flattened disc-like bodies (corpuscles) of a red colour, floating in a colourless liquid. These bodies vary in size and shape in different animals. Those of man have an average diameter of 1-3200th

of an inch, and a thickness of 1-12,400th, being larger than those of any of our domestic animals. Those of the elephant are the largest yet known among manmals (fig. 100). In oviparous vertebrates they are oval in form, and in the frog much larger than in man. When dried they form in man, on an average, about 13 per cent of the whole weight of the newly-drawn blood. In a moist state they form little more than half its weight; 100 parts of the moist corpuscles contain 57 of water and 43 of solids, the main constituents of the latter being *haemaglobin*, a colourless substance (*globulin*), which belongs to the same class of chemical compounds as gluten, albumen, and fibrin, and a small portion of saline matter. Among the most interesting facts connected with the corpuscles is the relation which this saline matter bears in kind to that of the whole blood.

We have already seen that the blood contains a considerable proportion of saline or mineral matter—about 8 parts in 1000 of fresh blood; so that, when dry blood is burned, it leaves about 4 per cent of ash. The chief ingredients of this ash are common salt and chloride of potassium; the rest consists of potash, soda, lime, magnesia, oxide of iron, phosphoric acid, and sulphuric acid. Of these substances, the potash, the phosphoric acid, and the iron, are principally contained in the corpuscles; while the common salt especially abounds in the colourless liquid or serum in which the corpuscles are seen to float.

Countless absorbent vessels are continually bringing new liquids, and pouring them into the blood, and almost as many are continually removing from the blood certain portions of its contents, and yet this relative position of its saline constituents is continually maintained. The corpuscles allow some of these substances to pass abundantly into their interior, while others of them are in a great measure excluded. This separation is probably effected with a view to the after-formation of flesh, since the animal flesh agrees with the corpuscles of its blood in containing much potash and phosphoric acid, with comparatively little common salt.

It is very interesting to observe how, in so important a fluid as the blood, the several substances it contains thus separate themselves into distinct groups with a view to

after uses. Each corpuscle is, in fact, a minute microcosm, within which chemical changes take place independent, in a sense, of all around it. These changes occur under a dominant direction working towards a rigidly definite end, and are therefore called vital. At the same time, a jealous discriminating power, as it were, guards the corpuscles by which this substance is admitted and that one refused a passage.

But, indeed, a discrimination of this kind appears to reside in all parts of the body. All are endowed with the power of selecting from the universally nourishing blood the chemical compounds which are specially required for the formation of their own substance, or the discharge of their special functions. Thus the bones specially select and appropriate phosphate of lime, while the muscles take phosphate of magnesia and phosphate of potash. The cartilages build in soda, in preference to potash. The bones and teeth specially extract fluorine. Silica is almost monopolised by the hair, skin, and nails of man, and by the horns, hair, and feathers of animals. Iron abounds chiefly in the colouring matter of the blood (*hæmaglobin*), in the black pigment of the eye, and in the hair. Sulphur exists largely in the hair, and an organic compound of phosphoric acid in the brain. Thus, to each part of the body certain chemical substances seem to be most specially appropriated, and to each part a peculiar and special power has been given of selecting out of the common storehouse those materials which suit it best to work withal.

And what is still more admirable, the formation and renewal of each part of the body serves the definite purpose of preparing the blood for the production or renewal of the next part it visits as it flows along. Thus the blood is continually changing as it proceeds in its course, leaving and taking up something at every new spot, and by these changes being always rendered more fit for the next duty it has to perform—(PAGET). If we look at the gases dissolved in the blood we shall find a beautiful illustration of this fact. Let us compare the arterial blood refreshed and purified in the lungs with the venous blood[1] from a muscle at rest:—

[1] See, for another analysis of the gases of blood, p. 488.

	Measures of Oxygen.	Measures of Carbonic acid gas.
100 measures of *arterial* blood contain, . .	17	30
100 measures of *venous* blood contain, . .	6	35

Nor is it less interesting to observe how every function of the body is on the alert, as it were, to keep the whole system in working order.

That the blood may subserve its various uses, its natural composition, though continually changing, as I have said, must not be materially altered. It may vary in composition within certain small limits; but when changed beyond these limits, the functions of the whole body begin to be deranged. Hence such a change is carefully provided against.

If, for example, much water is poured into the stomach, the chyle is diluted, the lacteals convey a thin fluid to the blood-vessels, and the blood itself becomes more watery than usual. But instantly to remedy this, the lungs, the skin, and the kidneys of the healthy man become more active, the excess of water is carried off, and the blood is thickened again to its usual condition. And so some kinds of food tend to increase the quantity of fat in the blood, others that of albumen, others that of common salt, &c., beyond the average proportion; but the ever-ready removers begin their more active work before any such excess becomes sensible in the healthy man, and continue it till the natural condition is restored.

But the unsleeping activity of the vessels which remove from the blood what it ought nowhere to contain in very sensible proportion, is most remarkably shown by the rapidity with which they carry off those refuse substances which are derived from the natural waste of the tissues. The lacteals are continually conveying new materials to the blood, to rebuild the wasting portions of the body. Of course the changed substance of the wasted tissues is poured into the blood quite as fast. But so diligent are the vessels and organs whose duty it is to remove this now useless matter, that mere traces of it only can ever be detected in the blood of a healthy man. The kidneys, especially, are on the alert to pick it up, to hurry it away from the blood as rapidly as it appears, and to discharge it by way of the

urine. The kidneys are thus the chief cleansers of the vital fluid, so far as its *non*-volatile or fixed impurities are concerned. In immediate importance to life they stand next to the lungs. We may cease for days to carry food into the body without serious injury to life; but let the removers intermit their operations for a single day, and the blood would become loaded with poison, and the animal precipitated into dangerous disease.

The natural cravings of the animal appetite for special kinds of food are rich in curious chemical phenomena. The formation of blood, and the maintenance of the animal heat, require the introduction into the stomach of certain chemical forms of matter (gluten, fat, starch, &c.) in certain proportions. The adult man should on the average take for his daily ration not only a certain amount of food-substances (*nutrients*), but he should adjust their relation to one another. The amount per day may be somewhat as follows :—

	lb.	oz.
Water,	5	$8\frac{3}{4}$
Albumen, fibrin, &c.,	0	$4\frac{1}{4}$
Starch, sugar, &c.,	0	$11\frac{1}{2}$
Fat,	0	$3\frac{3}{4}$
Common salt,	0	$0\frac{3}{4}$
Phosphates, potash-salts, &c.,	0	$0\frac{1}{3}$

The total dry substance here amounts to 1 lb. $3\frac{1}{3}$ oz.

The ratio or proportion, assuming the water to be 100, will stand thus—

Water.	Flesh-formers, as albumen.	Heat-givers, as starch.	Salts.
100	5	22	1

If for a length of time the suitable proportions be disregarded, first the comfort of the body suffers, and subsequently its health. Such changes often proceed slowly, and become sensible only after many years elapse; but the slightest derangements make themselves felt at last, so as seriously to affect the constitutions of whole families and tribes of men.

It is very striking, therefore, to observe how, by a kind of natural instinct, the inhabitants of every country have contrived to mix up and adjust the several kinds of food within their reach, so as to attain precisely the same physiological

end. The Irishman mixes cabbage with his potatoes; the Englishman, bacon with his beans, or milk and eggs with his starchy foods; the Italian, rich cheese with his macaroni; and the natives of India, gram and other pulse rich in gluten with their rice and millet. These, and other methods mentioned in previous chapters, exhibit so many purely chemical ways of preparing mixtures nearly similar to each other in composition and nutritive value. In the most rude diet, and in the luxuries of the most refined table, the main cravings of animal nature are never lost sight of. Besides the first taste in the mouth, there is an after taste of the digestive organs which requires to be satisfied. An indifferent cook may gratify the first; he is no mean physiological chemist who can at the same time fully satisfy the second.

Even the water we drink is an important element in a well-considered and properly-adjusted diet. It by no means follows in all cases, perhaps not even in the majority, that the purest water is the best for the health of a given family, or for the population of a given district. The bright sparkling hard waters, which gush out in frequent springs from our chalk and other limestone rocks, are relished to drink, not merely because they are grateful to the eye, but because there is something exhilarating in the excess of carbonic acid they contain and give off as they pass through the warm mouth and throat; and perhaps because the lime they hold in solution neutralises acid matters from the stomach, and acts as a grateful medicine to the system. To abandon the use of such a water, and to drink daily in its stead one entirely free from mineral matter and dissolved oxygen and carbonic acid gas, so far from improving, may injure the individual or local health.

And so the nature of the water of a country may even have something to do with the choice of a national diet. The human body, for example, requires a certain proportion of lime to be contained in or mixed with its food. If the common diet do not contain a sufficient proportion of this mineral ingredient, the common water of the country may supply the deficiency; and thus a national mode of living may spring up, the salutary properties of which depend partly upon the food and partly upon the water. In another district or country, where the drinking-water is different, the same

solid food, eaten alone, may be unsuited for the maintenance of health.

In this way it will appear that the reasons for the adoption of a peculiar national diet may lie much deeper than political economy can generally go. It may depend upon refined chemico-physiological and chemico-geological relations, the discovery of which we may be very long indeed in arriving at.

It is the same with artificial beverages as with articles of ordinary drink and diet. An unthought-of chemical instinct has guided men in the selection of these also. The ancient Abyssinian and the modern Arabian had their coffee, the Chinese and Tartars their tea, the South American aborigines their maté, and the Mexicans their cocoa, ages before any chemical knowledge existed as to the nature of the substances contained in them. What constitutional cravings common to us all have prompted to such singularly uniform results! Through how vast an amount of unrecorded individual experience must these results have been arrived at!

And so with what we call condiments, similar instincts have their play. The wild buffalo frequents the salt-licks of North-western America; the wild animals in the central parts of Southern Africa are a sure prey to the hunter who conceals himself beside a salt spring; and our domestic cattle run peacefully to the hand that offers them a taste of this delicious luxury. Yet salt, though often used as a flavourer or regarded as nothing more, is really an essential part of our food,—its sodium supplying that element to the bile, its chlorine furnishing hydrochloric acid for the gastric juice. From time immemorial it has been known that without salt man would miserably perish; and among horrible punishments, entailing certain death, that of feeding culprits on saltless food is said to have prevailed in barbarous times. Maggots and corruption are spoken of by ancient writers as the distressing symptoms which saltless food engenders; but no ancient or unchemical modern could explain how such sufferings arose. Now we know why the animal craves salt, why it suffers discomfort, and why it ultimately falls into disease if salt is for a time withheld. Upwards of half the saline matter of the blood consists of common salt; and as this is partly discharged every day through the skin and the kidneys, the necessity of continued supplies of it to the

healthy body becomes sufficiently obvious. The bile also contains soda as a special and indispensable constituent, and so do all the cartilages of the body. Stint the supply of salt, therefore, and neither will the bile be able properly to assist the digestion, nor the cartilages to be built up again as fast as they naturally waste.

And yet what shows this craving for salt to arise out of a refined species of instinct similar to that which may have fixed many national dietaries, is the fact that neither man nor animals are everywhere eager for or even fond of salt. Mungo Park describes salt as "the greatest of all luxuries in Central Africa."[1] But the Damaras, in South-western Africa, never take salt by any chance; and even Europeans, travelling in their country, never feel the want of it. But the well-water in Damara land is nearly always brackish or saline, though it appears to taste rather of carbonate of soda than of the chloride. Their neighbours, the Namaquas, set no store by salt; the Hottentots of Walfisch Bay "hardly ever take the trouble to collect it;" and even the wild "game in the Swakop do not frequent the salt-rocks to lick them, as they do in America."[2] One tribe of New Zealanders hold salt in abhorrence.

In the colds of Siberia, also, as in the heats of Africa, a similar disregard of salt sometimes prevails. "Most of the Russians at Berezov eat their food without a particle of salt, though that condiment can easily be obtained at a trifling cost—a sufficient quantity of it being always kept at the government magazine, and sold at a moderate price. Indeed, were the price of salt even much higher, it could make no difference to the wealthier class of the inhabitants, who can so well afford every indulgence, and procure for their table the most expensive luxuries. But salt is not at all in use,

[1] "It would appear strange to a European to see a child suck a piece of rock-salt, as if it were sugar. This, however, I have frequently seen; although in the inland parts the poorer class of inhabitants are so very rarely indulged with this precious article, that to say a man eats salt with his victuals, is the same as saying he is a rich man. I have myself suffered great inconvenience from the scarcity of this article. The long use of vegetable food creates so painful a longing for salt, that no words can sufficiently describe it."—MUNGO PARK.

[2] Narrative of an Explorer in Tropical South Africa, by Francis Galton, p. 183.

and hence I am led to the conclusion that their taste is such as not to require with their food that condiment, which is everywhere else considered indispensable. Their soups, vegetables, and even roast meats, are prepared and eaten without salt."[1]

The explanation of these cases, so inconsistent with our general experience, is found in the refined instinct of the body itself. When the food we usually eat conveys a sufficiency of salt into the body, it has no occasion for more. It therefore feels no craving for it, shows no liking to it, and takes no trouble to obtain it. And doubtless, in the kind of food and drink consumed in the Damara country, and by the Russians of Berezov, either more salt, or more of sodium and chlorine, in other combinations, than is usual among us, is conveyed into the stomach, or their habits render less salt necessary to them, or cause less of it to be daily removed from their bodies.

Nor is the refined delicacy of the instinctive perception of the living body, in this case, more wonderful than that marvellously delicate susceptibility to the influence of minute quantities of matter which we have seen it to be, in so many instances, capable of displaying. The narcotics which exercise so remarkable a power over us act upon the system in quantities which are inappreciably small. The beverages we prepare exhilarate and strengthen by almost infinitesimal doses of the active ingredients they contain. The odours we enjoy come floating to the nostrils in molecules of inconceivable minuteness and tenuity; while neither by weight nor by measure can we estimate the fatal miasmata which carry fever and plague wherever they penetrate.

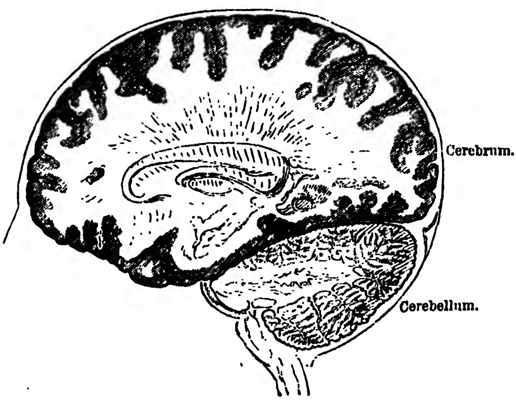
Equally delicate and mysterious is the relation which our bodies bear to the passing light. How our feelings, and even our appearance, change with every change of the sky! When the sun shines, the blood flows freely, and the spirits are light and buoyant. When gloom overspreads the heavens, dulness and sober thoughts possess the mind. The energy is greater, the body is actually stronger, in the bright light of day; while the health is manifestly promoted, digestion hastened, and the colour made to play on the cheek, when the rays of sunshine are allowed freely to sport around us.

[1] Revelations of Siberia, by a Banished Lady, vol. ii. p. 195.

Want of space forbids me to advert at length to the solid materials of which the most important organs of the body consist. Yet the chemistry of these is everywhere equally delicate and refined. How wonderful, for example, the varying colour of that soft, pulpy, gelatinous matter (*corpus papillare*) which rests on the mucous network (*rete mucosum*) between our outer and inner skins! Black in the African negro, red in the North American Indian, yellow in the Asiatic, and white in the European, it gives the characteristic colour to each race of men. It is structurally the same in all, but for wise ends it differs chemically in each, so as to adapt each race for the conditions in which it is destined to live. And so for other wise ends, no doubt; but among these, to give beauty to the female countenance, the nearly pure white of the European neck changes chemically again, and becomes the bright and blushing rose on the blooming maiden's cheek.

And then the brain, the distinctive organ of the human race, what chemical novelties and peculiarities it exhibits. Cut across, the cerebrum, as shown in the annexed fig., 101,

Fig. 101.



In the above illustration, the shaded parts represent the grey substance of the cerebrum.

is seen to consist of a mass of white or medullary matter, bordered towards the outer edge by little inlets of a grey substance. In structure these two parts differ. The grey matter consists mainly of cells or vesicles grouped together

in mass. The white portion, again, consists of minute fibres, which proceed from the grey matter of the covering, and in part connect it with the grey masses lying in the interior. Then, as to function, the grey matter, though so small in quantity, is supposed to be the seat of the intellect. Softenings, tumours, and abscesses, may exist in the white part of the brain—a portion of it may even be extracted without seriously or universally affecting the mental powers; but compress the grey part ever so little, or otherwise alter or disturb it, and you at the same time seriously interfere with the processes of thought, and disturb the intellectual sanity of the individual.

Then, further, as to chemical composition, the whole brain and nervous tissue are distinguished by containing a large proportion of several chemical compounds of fat-like character, in some of which sulphur, and in others phosphorus, is present. These compounds are not yet thoroughly understood. The phosphorus, above named as one of their constituents, is present in an oxidised form as a *complex phosphoric acid.* To illustrate this, the following example will suffice: *Lecithin* is a conspicuous constituent of brain and nerves. It is a white, slightly crystalline substance, easily soluble in alcohol, and readily decomposed by a heat below boiling water, and by almost every chemical reagent. Now lecithin is a complex substance, containing, it is believed—

Carbon, . .	44 atoms.	Hydrogen, . .	90 atoms.
Nitrogen, . .	1 atom.	Phosphorus, . .	1 atom.
Oxygen, ...	9 atoms.		

When it is decomposed it usually unites with water, and may then form in succession—

1 of *lecithin* yields { 1 of *neurin* and 1 of *distearyl-glycerin-phosphoric acid*—which yields { 2 of *stearic acid* and 1 of *glycerin-phosphoric acid*—which yields { 1 of *glycerin* and 1 of *phosphoric acid.* } } }

The variety and complexity of the work done in the brain and nervous centres, of the processes of sensation, volition, and thought, are clearly related to the presence and change of such brain-constituents as lecithin. In chemical constitution, as in physical structure, the nervous substance is full of com-

plex arrangements. And in each important part of the brain and nerves, the proportions of the several ingredients differ from that which prevails in the other parts—no doubt that each may be better fitted to perform its proper work. Thus, the proportion of fat in the white is nearly three times as great as in the grey part, and that of water less in a corresponding degree. And again, the grey matter leaves a larger percentage of ash or mineral matter when burned, and its fatty part contains more phosphorus. Similar differences also prevail in the proportions of these constituents, both organic and mineral, in different portions of the white matter of the brain itself and of the numerous nerves, at different periods of life, and when under the influence of different diseases—so that in this marrow-like nervous matter, chemical adjustments are to be found as intricate and refined as in any other portions of our bodily economy.

I could have wished also to advert to the construction and chemical composition of the parts of the eye, to the chemical as well as physical adaptation of these several parts to the optical functions they perform, and to the composition and use of the tears by which it is occasionally bedewed; to the teeth, coated and often interwoven with a flinty enamel of an altogether peculiar nature; to the fluids that moisten the nostrils and ears, or that flow from the fat cells of the skin, each fluid chemically adjusted to its special work; and to many other topics of a similar kind connected with the chemistry of our everyday life. It is sufficient for my present purpose, however, to have shown that the molecular mechanism, so to call it, of the body we cherish, is not less wonderful than its anatomical structure—and that, though a little more profound and difficult to comprehend, it is not less worthy of being studied by the intelligent, the cultivated, or the reverential mind.

CHAPTER XXXIII.

THE CIRCULATION OF MATTER.

A RECAPITULATION.

Employment of matter for successive uses; popular ideas regarding.—Shakespeare's Hamlet.—Human saltpetre.—The circulation of water.—Ascent of vapour in tropical regions.—Evaporation from the leaves of plants.—Expulsion from the lungs and skin of animals.—Chemical circulation of water.—Circulation of carbon. Quantity of carbon in the atmosphere; how it is continually renewed.—Decay of shed leaves and bark, and yearly ripening herbage.—Breathing of animals.—Relations of air, plant, and animal, as regards this carbon.—Burying of carbon in the earth; restoration to the air by the burning of coal.—Carbon confined in limestone rocks; how the earth breathes this out again.—Circulation of nitrogen.—Gluten of plants.—Forms in which nitrogen exists in plants, in the soil, and in animals.—Restlessness of matter within the animal body.—Rapid waste of the blood and tissues; agency of oxygen in this waste.—Production of urea; change of this in the soil.—General scheme of the circulation of nitrogen; we cannot restrain it.—How part of the nitrogen escapes, and revolves in a wider circle.

THAT the same portion of matter may, in the operations of nature, be employed for various successive purposes, living and dead, has long been familiar to the popular mind. Philosophers of almost every age have speculated on the changes of matter, and poets have found scope for their imaginations on a subject at once so interesting and so indefinite. It is only from the results of modern scientific investigation, however, that clear and positive ideas have been obtained as to the nature, the necessity, and the connection of these natural changes. We now know not only that matter does

constantly change, but that it constantly circulates in a round of unceasing change. It has been shown that the transformations it undergoes are necessary to the existing condition of things; that they take place in a fixed and predetermined order; and that they are again and again renewed in an endlessly revolving succession.

There is a degree of rude sublimity in the curious reasoning of Hamlet, when he says: "Alexander died; Alexander was buried. Alexander returneth into dust; the dust is earth; of earth we make loam; and why of that loam, whereto he was converted, might they not stop a beer-barrel?

> 'Imperial Cæsar, dead, and turned to clay,
> Might stop a hole to keep the wind away.
> O that *that* earth which kept the world in awe,
> Should patch a wall to expel the winter's flaw!'"

And yet the matter-of-fact touch of modern knowledge turns the whole of this into an absurd conceit. The body of man crumbles into a handful of loose dust, it is true; but this dust is not earth, of which we can make loam to stop a gap or flaw withal; and thus, in the incorrectness of his facts, we forget the merits of the poet.

More might be made by a true poet of the fact related by Mr Squier, that the Romish priests at Leon, in Nicaragua, sell the burial-ground around their churches, for the use of their occupants, for periods of from ten to twenty-five years; "at the end of which time the bones, with the earth around them, are removed and sold to the manufacturers of nitre." [1] So that to the unexpected, warlike, and base use of making "villanous saltpetre," are the best and most peaceful of the Nicaraguan citizens yearly converted.

The words of Shakespeare and the fact of Squier may both suggest to us many reflections; but there is nothing positive in either of them, beyond the meagre moral, that what forms part of the living, cherished, almost worshipped body to-day, may be employed for most unexpected, and what appear most vile, purposes to-morrow. This limited truth formed the substance of all the ancients knew, and of all the moderns could say until very recently, regarding the changes and future fate of the animal body after the living spirit had left it. But this branch of natural knowledge has been so wonderfully

[1] Squier's Nicaragua, i. 384.

illustrated by the researches of the present and passing generations, that we can now follow the same particle of matter through a long series of successive visible transformations. To-day we can see it living in the plant, to-morrow moving in the animal; next floating as a constituent portion of the thin air, or rippling along as an ingredient of the clear brook; then resting for a while in the lifeless soil, waiting till the opportunity arrives for its commencing a new career.

It will not, I believe, be without interest to my readers, after perusing the details of the preceding chapters, if I briefly recapitulate in this place the substance of what has been already stated in regard to the changes of matter;—what is the nature of the transformations it undergoes; by what agencies they are brought about; and for what important end. I shall begin with the simple, and advance to the more complicated.

I. The Circulation of Water.—The simplest form of the circulation of matter is that which is presented by the watery vapour contained in the atmosphere. From this vapour the dews and rains are formed which refresh the scorched plant and fertilise the earth. The total yearly depth of dew which falls we cannot estimate. On summer evenings it appears in hazy mists, and collects on leaf and twig in sparkling pearls; but at early dawn it vanishes again unmeasured—partly sucked in by plant and soil, and partly dispelled by the youngest sunbeams. But the yearly rainfall is easily noted. In our island it averages about 30 inches in depth; and in Western Europe generally, it is seldom less than 20 inches. Among our Cumberland mountains in some places a fall of 200 inches a-year is not uncommon; while, among the hills near Calcutta, as much as 550 inches sometimes fall within six months. Here let it be noted that an inch of rain corresponds to a weight of water of 101 tons per acre.

Now, as the whole of the watery vapour in the air, were it to fall at once in the form of rain, would not cover the entire surface of the earth to a depth of more than five inches—(Dr Prout)—how repeated must the rise and fall of this watery vapour be! To keep the air always duly moist, and yet to maintain the constant and necessary descent of dew and rain,

the invisible rush of water upwards must be both great and constant.

The ascent of water in this invisible form is often immediate and obvious, depending solely upon physical causes. But it is often also indirect; and, being the result of chemical or physiological causes, is less generally perceptible. Thus—

1°. Water circulates abundantly between earth and air through the agency of purely physical causes. We see this when a summer shower, falling upon our paved streets, is speedily licked up again by the balmy winds, and wafted towards the region of clouds, ready for a new fall. But, on the greatest scale, this form of circulation takes place from the surface of the sea in equatorial regions, heated through the influence of the sun's rays. Thence streams of vapour are continually mounting upwards with the currents of ascending air, and with these they travel upwards to colder regions of air, or north and south, till lower temperatures or colder climates precipitate them in dew, rain, or snow. Returned to the polar or temperate seas by many running streams, these precipitated waters are carried back again to the equator by those great sea-rivers which mysteriously traverse all oceans, and, when there, are ready to rise again to repeat the same revolution. How often, since time began, may the waters which cover the whole earth have thus traversed air and sea, taking part in the endless movements of inanimate nature!

2°. Again, physiological causes, though in a less degree than the physical, are still very largely influential in causing this watery circulation.

Thus the dew and rain which fall, sink in part into the soil, and are thence drunk in by the roots of growing plants. But these plants spread out their green leaves into the dry air, and from numberless pores are continually exhaling watery vapour in an invisible form. From the leafy surface of a single acre in crop, it is calculated that from 3,000,000 to 5,000,000 lb. of water are yearly exhaled in the form of vapour in our island; while, on an average, not more than 2,500,000, fall in rain. Whether the surplus thus given off be derived from dews or springs, it is plain that this evaporation from the leaves of plants is one of the more important forms which the circulation of water assumes.

So animals take into their stomachs another portion of the same water, and, as a necessary function of life, are continually returning it into the air from their lungs and their insensibly reeking hides. About 2 lb. a-day are thus discharged into the air by a full-grown man, and larger animals give off more, probably, in proportion to their size. Multiply this quantity by the number of animals which occupy the land surface of the globe, and the sum will show that this also is a form of watery circulation which, though less in absolute amount than the others I have mentioned, is yet of much importance in the economy of nature.

3°. But water circulates also, in consequence of unceasing chemical operations, in a way which, if less obvious to the uninstructed, is, if possible, more beautiful and more interesting than the mere physical methods above described.

We have seen that the main substances of plants—their cellulose and starch and sugar—consist in large proportion of water. 100 lb. of each of these three substances may be regarded as consisting respectively of—

	Cellulose and starch.	Cane-sugar.
Water, ...	55½	58
Carbon, ...	44½	42
	100	100

Now, as the plant grows, water from the soil or from the air unites chemically with carbon, and forms the cellulose of its stem, the sugar of its sap, and the starch of its seed. When the plant dies and decomposes in the air, the water is again set free from its woody stem. Or when the animal digests the starch or sugar, the water which these contain is discharged from its lungs and skin.

Thus the living plant works up water into its growing substance, the elements of which water the decaying plant and the breathing animal again set free, as water; and thus a chemical circulation continually goes on, by which the same water is caused again and again to revolve. Within a single hour it may be in the form of starch in my hand, be discharged as watery vapour from my lungs, and be again absorbed by the thirsty leaf to add to the substance of a new plant.

II. The Circulation of Carbon.—The above chemical

form of water-circulation will be rendered more clear by tracing the still more beautiful circulation of carbon.

Carbonic acid gas is now familiar to my readers as that sparkling air which, rising in countless bubbles, gives life to the creaming tankard, to the tempting champagne, and to the more innocent soda-water. This gas, as I have already explained, consists of carbon and oxygen only, and is an essential constituent of our atmosphere. It exists, it is true, only in small proportion in the air. Every 2500 gallons of the air at the level of the sea contain only one gallon of the gas; yet upon the constant presence of this small proportion, the continuance of all vegetable life depends.

This dependence appears more striking to us, however, the more precise our ideas become as to the absolute quantity of this substance which the entire air contains. The whole weight of the atmosphere is about 15 lb. to the square inch, and of this the carbonic acid forms somewhat less than 120 grains, containing about 33 grains of carbon. Now living plants are continually sucking in this gas by their leaves; and the operation goes on so rapidly, that were the entire surface of the earth dry land and under cultivation, crops such as we generally reap from it would extract and fix the whole of the carbon in the form of vegetable matter, in the short space of twenty-two years! And if a flourishing beech-forest covered the whole earth, eight years would suffice to exhaust the entire atmosphere of its carbonic acid gas. Were this to happen, vegetation would cease. But such a catastrophe is prevented by the constant restoration of carbonic acid to the air through the unceasing operation of preservative causes. Thus—

1°. The trees of the forest yearly shed their leaves, or in Australia their bark. Through the influence of the weather these waste portions, and their roots also, in a measure decay and disappear, restoring again to the atmosphere a portion of the same carbon which the living tree had previously extracted from it during the period of their growth. The yearly ripening herbage also, and every plant that naturally withers, on plain or hill—the grass of the burning prairie, and the timber of inflamed forests—with all that man consumes for fuel and burns for other uses;—every form of

vegetable matter, in short, when exposed to the action of air or fire, returns, more or less quickly, to the state of carbonic acid, and disappears in the invisible atmosphere. Thus, what is yearly withdrawn from the air by living plants, is so far restored again by those which naturally perish, or which are destroyed by the intervention of man.

2°. But man himself and other animals assist in the same chemical conversion. They consume vegetable food, with the same final result as when it perishes by natural decay, or is destroyed by the agency of fire. It is conveyed into the stomach in the form in which the plant yields it. The green herb, the perfect seed, and the ripe fruit, are eaten and digested; then forthwith they are breathed out again from the lungs and the skin, in the form of carbonic acid and water. But we can follow this operation more closely, and it will be both interesting and instructive to do so.

The leaf of the living plant sucks in carbonic acid from the air, and gives off the oxygen contained in this gas. It retains almost exclusively the carbon. The roots drink in water from the soil, and out of this carbon and water the plant forms starch, sugar, fat, and other substances. The animal introduces this starch, sugar, or fat into its stomach, and draws in oxygen from the atmosphere by its lungs. With these materials it undoes the previous labours of the living plant, delivering back again, from the lungs and the skin, the elements of the starch and the oxygen in the form of carbonic acid and water. The process is clearly represented in the following scheme:

	Takes in	Produces
THE PLANT	*Carbonic acid* by its leaves; *Water* by its roots.	*Oxygen* from its leaves; *Starch, &c.*, in its solid substance.
THE ANIMAL	*Starch and fat* into the stomach; *Oxygen* into the lungs.	*Carbonic acid and water* from the skin and the lungs. *Fat* in the animal's body.

And this fat, laid up for a while in the body, is in its turn also breathed away in carbonic acid and water.

Thus the circle begins with carbonic acid and water, and ends with the same substances. The same materials—the same carbon, for example—circulates over and over again, now floating in the invisible air, now forming the substance

of the growing plant, now of the moving animal, and now again dissolving into the air, ready to begin anew the same endless revolution,—the plant, continually *unburning* the *burnt* products made by the animal, and *vice versâ*. It forms part of a vegetable to-day—it may be built into the body of a man to-morrow; and a week hence, it may have passed through another plant into another animal. What is mine this week is yours the next. There is, in truth, no private property in ever-moving matter.

3°. Yet all the carbonic acid which is removed from the air by the agency of plants, is not immediately restored by the circulation above described. Two larger wheels revolve to make up the deficiency.

It has been shown that when plants die and decay, are burned into the air, or are eaten by animals, the carbon they contain is delivered back again to the atmosphere in the form of carbonic acid. But all the plants produced yearly over the whole earth are not so resolved into gaseous substances in any given time. In all parts of the world, and during all time, some portions of vegetable matter have escaped this total destruction, and have been buried beneath the surface of the earth, to be preserved in the solid form for an indefinite period. With such comparatively indestructible forms of vegetable matter we are familiar in the peat-bogs of Scotland and Ireland—sometimes from 50 to 100 feet deep—and in the submarine forests which are seen in so many parts of our island-shores. We are still better acquainted with them, however, in those vast deposits of coal which a kind Providence, long ago, brought together and covered up. What is and has been thus collected and gradually buried would necessarily cause a constant diminution in the small quantity of carbonic acid contained in the air, were there no natural means in operation for making up the yearly loss.

The means we are most familiar with for repairing this waste, are those which man himself brings into operation. At a certain period in his history, half-civilised man discovered the use of coal. At a more advanced period he found out how to dig deep and hollow out mines in search of it; and, at a still later period, how to employ it for a thousand beneficial purposes. In burning coal, we cause its carbon to unite with the oxygen of the air, and to disappear in the

state of carbonic acid. We restore it to the atmosphere again in the state in which it existed there, perhaps a million of years ago, when it was sucked in by the growing plants, and, in the form of vegetable matter, afterwards buried beneath the earth's surface. In raising and consuming coal, therefore, we are, to a certain extent, undoing and counteracting the yearly lessening of the carbon in the air, which appears to ensue from the yearly covering up of a portion of vegetable matter. The 300,000,000 tons of coal which are now yearly consumed throughout the globe, produce about 800,000,000 tons of carbonic acid gas. How far this quantity serves to compensate for what is constantly buried up again it is impossible to estimate. It must be acknowledged, however, that the coal-fires we burn are an important subsidiary agent in promoting the circulation of carbon on the globe.

But we burn wood, and peat, and turf, in addition to coal and gas—and we also consume oil, and wax, and many vegetable and animal fats; these all yield carbonic acid gas to the air. More than this, every lime-kiln, every vat of fermenting beer-wort, every heap of decaying leaves or of animal refuse, contributes something to the world's stock of atmospheric carbonic acid gas.

4°. Again, within the bosom of the great seas, tiny zoophytes are at work, upon which nature has imposed, in addition to the search for food and the care of their offspring, the perpetual labour of building new houses. The common shell-fish of our coasts toil continually for defence as well as for shelter, repairing, enlarging, and renewing their own dwelling-places; and as they die, each drops its shell as a feeble contribution to the beds of shelly limestone which are here and there forming at the bottom of our deep seas.

In more southern waters again, still humbler animals build up beneath the waves massive coral walls thousands of miles in extent, which, now skirting long coast-lines and now encircling solitary islands, bid defiance to the angriest storms. And these, too, as they die, generation after generation, leave, in rocky beds of coralline limestone, an imperishable memorial of their exhaustless labours. These rocks contain, chained down in a seemingly everlasting imprisonment, two-fifths of their weight of carbonic acid. This has been all withdrawn either directly or indirectly from the atmosphere; and thus,

through the rock-forming living things it contains, the sea must ever be drinking in and storing up the carbonic acid of the air.

And the same process has been going on almost continuously since the world began. Vast coral-reefs lie buried beneath our beds of coal, and mountains of thick-ribbed shelly limestone have been lifted from ancient seas before these older reefs were formed. The labours of marine animals, therefore, like the burying of vegetable matter, must throughout all time have been causing a daily lessening of the absolute quantity of carbonic acid in the atmosphere,—unless some other natural operation has meanwhile been making compensation for this constant removal.

5°. But the earth herself breathes for this purpose. From cracks and fissures, which occur in vast numbers over the surface of the earth, carbonic acid gas issues in large quantities—sometimes alone, and sometimes along with springing waters—and daily mingles itself with the ambient air. It sparkles in the springs of Carlsbad and Seltzer; rushes, as if from subterranean bellows, on the table-land of Paderborn; astonishes travellers in the Grotta del Cane; interests the chemical geologist in the caves of Pyrmont, and among the old lavas of the Eifel; and is terrible to man and beast in the fatal "Valley of Death," the most wonderful of the wonders of Java. And besides, it doubtless issues still more abundantly from the unknown bottom of the expanded waters which occupy so large a proportion of the surface of the globe. From these many sources, continually flowing into the air or rising into the sea, carbonic acid is, and has been, daily supplied in place of that which is daily withdrawn, to be buried in the solid limestones of the globe. Did we know after what lapse of time the earth would again breathe out what is thus daily entombed, we should be able to express in words how long this slowly revolving secular wheel requires fully to perform one of its immense gyrations.

Thus, like the watery vapour of the atmosphere, its carbonic acid also is continually circulating. While that which floats in the air, circles from the atmosphere to the plant, from the plant to the animal, and from the animal to the air again,—many times, it may be, during one single generation —never really the property of any, and never lingering long

in one stay,—the whole created carbon is slowly moving in a greater circle between earth and air. It rises from the earth at one end of the curve in the state of an elastic gas, it amuses itself by the way in assuming for brief intervals many successive varieties of plant-form and animal-form, till it is finally buried in the earth again, at the other end of the curve, in the state of blackened fossil plants, or beds of solid limestone.

III. Circulation of Nitrogen.—We advance now to a circulation a little more complicated in its character, and one less thoroughly understood, but, if possible, still more interesting to us, because it is more closely connected with our own personal history, both physiological and domestic.

I have already described how, if a portion of wheaten flour be made into dough, and this dough be washed with water upon a sieve or on a piece of muslin, as long as the water passes through milky, there will remain upon the sieve a tenacious adhesive substance like bird-lime, which is known by the name of gluten; and how, again, if the milky water be allowed to settle, a white powder collects at the bottom, which is common wheaten starch.

Fig. 102.

By this process the flour of wheat is separated into two very different chemical substances,—starch and gluten. Of these two it chiefly consists, and in this respect it is the type of all other vegetable productions which are used as food. They all contain, as their principal constituents, two classes of substances, which are represented respectively by the starch and gluten of wheat. In tracing the circulation of carbon, we have already seen what becomes of the starch of

plants when consumed by animals; we are now to follow the changes in which their gluten takes a part.

Gluten is distinguished from starch and fat by containing nitrogen. This nitrogen is the kind of air which forms nearly four-fifths of the bulk of the atmosphere. It exists also in ammonia,—the well-known compound substance which gives their pungent odour to the liquid hartshorn and smelling-salts of the shops,—and in aquafortis, familiar to chemists by the name of nitric acid. These two compound bodies, ammonia and nitric acid, exist and are formed in the soil, and from the soil these substances are taken up by the roots of plants. In the interior of the plant, these substances are subjected to new influences; new chemical changes take place, in which they bear a part; and by means of the nitrogen they contain, gluten is formed. The many intermediate changes which follow each other within the vegetable sap we do not as yet understand; but we do know that the nitrogen which existed as ammonia and nitric acid in the soil, assumes, after these changes, the final form of gluten within the plant.

And now I have only to recall to the minds of my readers another chemical analogy, to enable them to follow this same nitrogen through still further changes. In treating of the natural relations which exist between animal and vegetable food, I have shown that the fibrin or main constituent of the animal muscle, and the white or albumen of the egg, are nearly the same thing in composition and general properties as the gluten of wheat. They all contain nitrogen in nearly the same proportion, and probably in a similar state of chemical combination. When the animal consumes vegetable food, therefore, it introduces into its stomach the very substance of its muscles and blood — the ready-formed materials out of which its several parts are to be built up. It does this, in fact, to build up and renew its several parts by means of this vegetable substance. The gluten of the plant is transformed into the flesh and tissues of the living animal.

Thus the nitrogen of the soil, through the intermedium of the plant, has attained to its highest dignity as a part of the body of breathing and intellectual man.

But having attained this most perfect form, the restless elements soon grow weary, so to speak, of their new dignity. Not only is the living body in constant movement as a whole,

but all its parts, even the minutest, are in perpetual motion. They are like the population of a great city, moving to and fro, coming and going continually, weeded out and removed hour after hour by deaths and departures, yet as unceasingly kept up in numbers by new incomers ;—changing from day to day so insensibly as to escape observation, yet so completely, that after the lapse of a few years, scarcely a known face can be discovered among congregated thousands. And so rapid is the tear and wear of the animal machine, to change our figure, in consequence of this incessant movement, that the repairs which are constantly called for have been said to be equal in extent to such as would renovate the greater part of the framework in less than a month. New materials are brought in for the purpose, while the old are thrown away and rejected.[1] Scarcely has the gluten of the plant been comfortably fitted into its place in the muscle, the skin, or the hair of the animal, when it begins forthwith to be dissolved out again—to be decomposed and removed from the body. Restlessness, beyond our control, is thus inherent in the very matter of which we are formed.

A brief summary will show how and in what forms this taking down and removal of the bodily substance is so rapidly effected.

The living animal absorbs, as we have seen, much oxygen from the air by its lungs. This oxygen is employed to convert the carbon and hydrogen of a certain part of its food into carbonic acid gas and water. This inhaled oxygen is, in fact, the agent through which the change of matter is effected. The muscle, for example, combines with oxygen, and, after several intermediate transformations, is finally changed into substances called urea, uric acid, &c., which pass away through the kidneys. This urea and uric acid return to the soil, from which the nitrogen they contain originally came. There they are gradually converted into ammonia, nitric acid, and other substances such as the plant roots originally took up, and which, now re-formed, are ready again to enter into new roots, and thus to recommence the same round of change.

But the animal does not extract and work up all the gluten of the vegetable food it eats. A part of it escapes digestion,

[1] See "What, How, and Why we Digest."

and is rejected in the animal droppings. This mingles with the soil, and there, like the urea, &c., is changed into ammonia and nitric acid. The same happens to the gluten of vegetables which die, and, without entering the stomach, undergo direct natural decay in the air or in the soil. Animal bodies themselves die also at last, and, like the vegetable gluten, pass through those successive changes which we call putrefaction and decay. As the result of these changes, the nitrogen they contain is again made to assume those forms in which plants are able to take it up, and to convert it into their own substance.

Thus, after various turns of the wheel, most of the nitrogen that entered the plant in the form of ammonia and nitric acid, returns again to the soil in one or other of the same states. Some of the matter revolves a time or two less, returning at once from the plant to the soil without passing through the animal at all, or at once from the muscle to the soil without undergoing the ordeal of the kidneys—but whether it runs one, two, or three heats, nearly all arrives, sooner or later, at the same goal, ready to start again on the same race. A bird's-eye view of this circulation of nitrogen is presented in the following scheme:—

	Takes in	Produces
THE PLANT	Nitrogen, in the forms of ammonia and nitric acid, from the soil.	Gluten and similar compounds, as albumen.
THE ANIMAL	*a.* Gluten into the stomach in its vegetable food, and oxygen through the lungs.	*a.* Muscle and other tissues.
	b. Animal muscle, &c., into the stomach in its animal food, and oxygen through the lungs.	*b.* Urea, &c., in the liquid excretions.
THE SOIL	Urea, and other animal excretions; dead animals and plants.	Ammonia, nitric acid, and other compounds, containing nitrogen.

Thus we end where we began—the soil, the plant, and the animal being involved in one never-ceasing, mutually-dependent revolution. We need scarcely concern ourselves, therefore, for the destiny of the organic part—the tissues and blood of our bodies. Its fate is decided by fixed and unerring laws. When it has served our purpose, new and immediate uses await it.. We attempt in vain to detain it

from predetermined labours, or, by the arts of the embalmer, to compel it to perpetuate a loved and honoured form. We need not wait even, as in Hamlet's supposition, for the body to crumble into dust. The fluids and tissues decompose rapidly, and are quickly dissipated; so that what is now part of the body of a Cæsar or a Venus, may literally within a week become part of a turnip or of a potato.

Even here, however, or in respect to this organic form of matter, we obtain occasional glimpses of a still wider circle. While the same portion of matter, on the whole, goes round and round unceasingly, as we have described, a certain portion of the ammonia and other volatile compounds of nitrogen, which are produced by decaying animal and vegetable substances, rises in the form of gas or vapour, and escapes into the air. It rises also in unknown quantity from the lungs and skins of animals, in their breath and perspiration. This ammonia the rains of heaven wash out and bring back again to the earth—thus restoring it to the soil from which it originally came, and to the wants of vegetable life. But these very rains also carry down a portion of it directly into the sea, and, through the rivers, sweep it from the land. Yearly, also, a part of the ammonia, nitric acid, and other similar compounds, is by natural operations resolved into elementary nitrogen, and is thus lost to living plants.

To make up for this waste, nitric acid is continually formed in the air in minute quantity. The nitrogen and oxygen of the atmosphere unite to form this acid through the agency chiefly of electric discharges, which are continually passing through the air. Ammonia also is given off into the atmosphere from many sources, as from all active volcanoes; and both of these compound substances the falling rain dissolves and carries earthward, so that a part at least of the failing supplies of nitrogen, in an available form of combination, are continually kept up. Still the formation of nitric acid in the air from its elements hardly occurs on a sufficiently large scale for the needs of vegetable life. A long series of experiments indicates that not more than 10 lb. of nitric acid and ammonia annually fall upon an acre in the rain, while the wheat grain alone of an acre wants 30 lb. The difference may be made up, in the absence of manure, by

some obscure chemical process which goes on between the air and decomposing carbonaceous matter. When the latter oxidises, especially under certain electrical conditions, the free nitrogen of the air may, it appears, enter into union with some of its elements. But the whole subject of the circulation of nitrogen, and the adequate supply of it to vegetation, is obscure. Broadly speaking, we may affirm that man is powerless to effect the combination of nitrogen with hydrogen into ammonia, or of nitrogen with oxygen and hydrogen into nitric acid. As the known sources of fresh ammonia and nitric acid seem inadequate, and as some of the nitrogen compounds are always being decomposed, there must be some imperfectly recognised formation of these bodies going on, or the organic world would have ended its career ere this. Thus, from the great atmospheric reservoir a stream of nitrogen of unknown bulk flows down yearly to the earth in the forms of nitric acid, ammonia, and possibly other compounds; while a similar stream returns again yearly to the air in the form of elementary gas, after having probably many times gone through the cycle of changes in which gluten and fibrin take a part. Within what conceivable time could the nitrogen of the whole atmosphere take part in this slow circulation?[1]

[1] For an excellent account of the circulation of nitrogen see the Quarterly Journal of Science for 1878.

CHAPTER XXXIV.

THE CIRCULATION OF MATTER.

A RECAPITULATION.

Circulation of mineral matter.—General form of this circulation from the soil through the plant into the animal, and thence to the soil again.—Special form.—Circulation of phosphoric acid and of saline matter.—Shedding of leaves and annual decay of vegetable productions.—Course of mineral matter through the animal body.—Waste and death of the body, and its return to the soil.—General view of this circulation.—Its constancy and rapidity.—Vain attempts to preserve human dust apart.—Mummies, Pyramids, and Etruscan tombs.—The valley of Hinnom.—Customs in Thibet and the Himalayas. How the natural diminution of mineral plant-food is counteracted.—Even the sea gives back its spoils.—Interference of slow geological revolutions.—Lessons taught by all this.—Small quantity of matter on which all life depends.—Lessons of constant intelligent activity with a view to a definite end.—Purposes served by every movement of matter in living bodies.—How the plant waits upon and serves the animal.—Small change in the condition of things which would banish life from the world.—Man forms no part of the scheme of the universe.—His material insignificance the crowning lesson.

IV. The Circulation of Mineral Matter.—We must now trace the revolutions through which the dust also—the earthy, inorganic, incombustible, or mineral part of the animal—passes.

When a portion of a plant is burnt in the air, the organic or combustible part is dissipated, and disappears; but a small quantity of ash or mineral matter remains behind. The wood-ash left when trees are burned is a familiar example of this. In like manner, when any part of an

animal is burned in the air, a portion of ash remains unconsumed. I need scarcely add, that a portion of soil, treated in a similar way, leaves an abundant residue of earthy matter undissipated by the fire.

Now, in regard to the combustible part of the plant—which is made up almost exclusively of carbon, nitrogen, and the elements of water—differences of opinion are possible as to whether the raw materials for building it up are derived from the soil or from the air. They all exist both in air and soil, and may be derived from the one or from the other. But in regard to the mineral or incombustible part of the plant, there can be but one opinion. Mineral matter does not exist as a part of the atmosphere, and therefore the plant must derive all, or nearly all, it contains of this kind of matter from the soil in which it grows; although leaves are capable of absorbing mineral matters in solution in rain-water, and do frequently so absorb traces of it.

Again, as all which the animal body contains is derived either directly or indirectly from vegetable food, the mineral matter or ash it leaves when burned must have come to it from the soil through the plant. And as, further, when the animal dies, its body is sooner or later returned to the soil, we have again another complete cycle, in which the earthy matter of living things is the ever-moving body. It ascends from the soil into the substance of the plant, thence into the substance of the animal, and thence descends again into the mother earth, to begin, as in our other examples, a new and similar career.

But a more chemical examination of this mineral or earthy matter will make our aquaintance with this cycle still more interesting and instructive.

It is not any kind of earthy matter, indifferently, which the plant-root sucks up and builds into the substance of its growing stem and leaves. It selects, as it were, only the rarer and more precious materials of which the soil consists, and from among these, again, such as natural waters can more or less readily dissolve. Phosphoric acid, lime, magnesia, and certain kinds of saline matter, of which we may take common salt as the representative, are the most important of these substances. Generally speaking, these ingredients exist but sparingly in the soil. The productive-

ness of a tract of land, therefore, in so far as it depends upon their presence, is kept up either by a constant natural circulation of the same quantity of these matters, or by the addition of periodical supplies from some other source, equal in kind and amount to those which the yearly herbage carries away.

In uncultivated regions the natural circulation is short and simple. In natural forests, for example, where the leaves or bark are annually shed, and the trees periodically die, the mineral matter quits the soil for the plant as it grows, and again, when the plant decays, returns to the soil. It thus makes but a short stage from the earth to the plant, and from the plant back to the earth again. It is so also in natural meadows. Yearly, in autumn, the grass ripens, withers, and returns its mineral matter to the soil; and yearly, again, in spring, the young herbage grows up and feeds on the relics of the previous year.

The circulation, though less direct, is not much more protracted when the vegetable produce, as in cultivated regions, is almost entirely consumed by animals. It then enters into their stomachs, is dissolved or digested, and converted into blood. From this blood its several mineral constituents are taken up by vessels provided for the purpose, to be conveyed to the parts of the body where their services are required. The saline portion is retained by the blood and the tissues. The phosphoric acid in combination with lime, forming phosphate of lime, is chiefly deposited in the bones, and in combination with potash, as phosphate of potash, in the muscles.

The importance of the former of these compounds—the phosphate of lime—to the animal economy, becomes apparent when it is recollected that dry bones leave, on burning, two-thirds of their weight of a white ash, of which five-sixths consist of phosphate of lime. But its comparative importance appears still more manifest when we consider how large a proportion it forms of the whole mineral matter of the body. Thus, in a full-grown man,

The whole mineral matter is about	11½ lb.
The phosphate of lime about	8¾ ,,
And the other mineral matters, amongst which common salt exists to the extent of half a pound,	2¾ ,,

But though the mineral matter of the vegetable, when introduced into the animal's stomach, is thus distributed to different parts of the body, and although it for the most part becomes fixed, as it were, for a time in its most solid parts, this does not necessarily imply its withdrawal from circulation. For, as we have already seen, all the parts of the body, even the most solid, are in a constant course of alteration and renewal. To this law of change the bones are subject, like the softest parts, though in a minor degree, so that the phosphoric acid and lime which are carried into them by the blood and built into their substance to-day, are, at least to some extent, taken down and carried out again, along with the other refuse and waste materials of the body. And forthwith, as fast as they reach the soil, these mineral substances commence a new career.

Finally, the whole body dies at once, and all the mineral substances which it at the time contains, return directly to the earth from which they came. There they undergo, chiefly through the agency of the oxygen of the air, but assisted by various ferments both organised and unorganised, a final breaking-up or decomposition, by which they are again brought into states of chemical combination, in which they can enter usefully into the roots of plants.

Thus, what the plant took from the soil, the animal—partly as it works and wastes during life, and partly when it dies—returns to the soil again without any long delay. New plants are thus at liberty to work up again the old materials and to despatch them forthwith on a new voyage. This general succession of changes undergone by the mineral matter, which takes a part in the established order of vegetable and animal life, is briefly represented in the following scheme:—

	Takes in	Produces
THE PLANT	Phosphoric acid, lime, common and other salts, from the soil.	The perfect substance of plants (from volatile and mineral substances together).
THE ANIMAL	*a.* The edible parts of plants. *b.* The digested food in its body, with oxygen through the lungs.	*a.* Perfect bone, blood, and tissues. *b.* Phosphates and other salts in the excretions.
THE SOIL	Excretions of animals, dead animals and plants.	Phosphoric acid, lime, common salt, &c.

It may be that a careful hunter after human dust might scrape together as much of what thus returns to the soil as would "stop a hole to keep the wind away." But our chemical science teaches us that this animal earth is not the kind of stuff that plastic clays are made of, and that such vile uses are, after all, only imaginary slights, to which our cherished ashes can never be subjected. They have other appointed uses, from which, treat them as we may, they cannot long be withheld.

The plant, on the one hand, is so wonderfully framed, that it refuses to grow unless it can obtain the phosphoric acid, &c., which it is bound to gather up and supply to the growing animal. And it does this so well, that a plant can sometimes find what a chemist cannot—can analyse a soil better than he can. And the soil, on the other hand, is so poorly provided with these and other most needful substances, that plant and animal are both ordained to return without fail their borrowed materials to mother earth, when the term of their own lives has come. A duty is laid also upon each particle of matter, zealously to prepare for a new service as soon as each earlier commission is performed. Thus, a constant circulation of the same comparatively small quantity of mineral matter is secured. Thus, also, we can claim no personal property in any single atom of it. How idle it seems, then, to the cold chemical eye to cherish either affection or reverence for dead ashes! Do as we may, they can never long be prevented from connecting themselves with new forms of vegetable and animal life, in which we have no concern.

And how visibly rapid, in the majority of cases, is the passage of this substance of our bodies to new forms of life! Thousands yearly perish in the sea, and are at once swallowed, digested, and built into the forms of marine animals. Thousands more die and decay in waste places, where vegetable forms soon cover and feed upon them. Armies of fighting men strew, as they march over a thousand fields, the relics of their wasting strength. A single battle restores to the soil of a populous district, materials enough to build up the bodies of its inhabitants for many succeeding generations.

Nor do graveyards hold it more securely. Of how many bygone men and women has the mineral substance lived

anew in the village sheep which crop the green herbage of the tufted tombs! In how many affection-tended, ornamental cemeteries does the dust of those we love fatten the soil for the cherished trees and shrubs! And how long is the consecrated ground itself secure against the changes of successive times—the demands of new roads, new streets, new railways, and new sanitary enactments, or the still more ruthless innovations of religious and political revolutions?

Or embalm the loved bodies, and swathe them, as the old Egyptians did, in resinous cerements, and you but preserve them a little longer, that some wretched, plundering Arab may desecrate and scatter to the winds the residual dust. Or jealously, in regal tombs and pyramids, preserve the forms of venerated emperors and beauteous queens,—still some future conqueror, or more humble Belzoni, will rifle the most secure resting-place. Or bury them in most sacred places, beneath high altars,—a new reign shall dig them up and mingle them again with the common earth. Or, more careful still, conceal your last resting-place where local history keeps no record, and even tradition cannot betray you,—then accident shall stumble at length upon your unknown tomb, and liberate your still remaining ashes.

How touching to behold the vain result of even the most successful attempts at preserving apart, and in their relative places, the solid materials of the individual form! The tomb, after the lapse of time, is found and opened. The ghastly tenant reclines, it may be, in full form and stature. The very features are preserved—impressed, and impressing the spectator with the calm dignity of their long repose. But some curious hand touches the seemingly solid form, or a breath of air disturbs the sleeping air around the full-proportioned body—when, lo! it crumbles instantly away into an insignificant quantity of impalpable dust!

Who has not read with mingled wonder and awe of the opening of the almost magical sepulchre of an ancient Etrurian king. The antiquarian *dilettanti*, in their underground researches, unexpectedly stumbled upon the unknown vault. Undisturbed through Roman and barbaric times, accident revealed it to modern eyes. A small aperture, made by chance in the outer wall, showed to the astonished gazers a crowned king within, sitting on his chair

of state, with robes and sceptre all entire, and golden ornaments of ancient device bestowed here and there around his person. Eager to secure the precious spoil, a way is forced with hammer and mattock into the mysterious chamber. But the long spell is now broken—the magical image is gone. Slowly, as the vault first shook beneath the blows, the whole pageant crumbled away. A light smoky dust filled the air; and, where the image so lately sat, only the tinselly fragments of thin gold remained, to show that the vision and the ornaments had been real, though the entire substance of the once noble form had utterly vanished.[1]

For a few thousand years some apparently fortunate kings and princes may arrest the natural circulation of a handful of dust. But in what are they better than Cromwell, whose remains were pitilessly disturbed—than Wycliffe, whose ashes were sprinkled on the sea—than St Genevieve, whose remains were burned in the Place de Grève, and her ashes scattered to the wind—than Mausolus, whose dust was swallowed by his wife Artemisia—than the King of Edom, whose bones were burned for lime—or than King Pepin, and all the royal line of Bourbons, whose tombs were emptied by a Parisian mob?[2] In Turkey, as about Smyrna, abandoned cemeteries

[1] See Mrs Hamilton Gray's Sepulchres of Etruria. The fragments of the gold ornaments are in the collection of Lord Kinnaird at Rossie Priory.

[2] "They burnt on the Place de Grève the remains of St Genevieve, the popular patroness of Paris, and threw her ashes to the wind. . . . A decree of the Convention had commanded the destruction of the tombs of the kings at St Denis. The Commune changed this decree into an attack against the dead. . . . The axe broke the gates of bronze presented by Charlemagne to the Basilica of St Denis. . . . They raised the stones, ransacked the vaults, violated the resting-places of the departed, sought out beneath the swathings and shrouds embalmed corpses, crumbled flesh, calcined bones, empty skulls of kings, queens, princes, ministers, bishops. Pepin, the founder of the Carlovingian dynasty, and father of Charlemagne, was now *but a pinch of grey ash, which was in a moment scattered by the wind.* The mutilated heads of Turenne, Duguesclin, Louis XII., Francis I., were rolled on the pavement. . . . Beneath the choir were buried the princes and princesses of the first race, and some of the third—Hugues Capet, Philip the Bold, Philip the Handsome. They rent away their rags of silk, and threw them on a bed of quicklime. . . . They flung the carcass of Henry IV. into the common fosse. His son and grandson, Louis XIII, and XIV., followed. Louis XIII. was but a mummy; Louis XIV. a black indistinguishable mass of aromatics. Louis XV. came last out of his tomb. The vault of the Bourbons rendered up its dead—queens, dauphinesses, princesses, were

speedily relapse into their original condition of woods and fields—the tombs disappearing beneath vegetation, dust, and forgetfulness. Horses and cows browse amongst them at will. All these ashes are dissipated at last. Their empty tombs may remain—the houses of the dead, like the houses of the living, long surviving, as melancholy mementoes of the tenants for whom they were erected.[1]

There is a barbaric philosophy, therefore, as well as an apparent knowledge of the course of nature, in the treatment of the dead which prevails in Thibet and on the slopes of the Himalaya. In the former country the dead body is cut in pieces, and either thrown into the lakes to feed the fishes, or exposed on the hill-tops to the eagles and birds of prey. On the Himalayan slopes, the people of Sikkim burn the body and scatter the ashes on the ground. The end is the same among

carried away in armfuls by the workmen, and cast into the trench."—Lamartine, History of the Girondists, book lii. § 23. A brief interval of proud separation, and they were mingled with the common dust!

From all this desecration only the remains of Turenne escaped. Rescued by a patriotic admirer from the hands of the destroyers, they were at first concealed in an obscure corner of the Jardin des Plantes, and afterwards consigned to the care of M. Alexandre Lenoir, among other curiosities he had collected in the Museum of the Petits Augustins. In September 1799 they were transferred from this place by Napoleon, then consul and a conqueror, to a splendid tomb prepared for them beneath the dome of the Invalides, and there deposited with much state—"where," says M. Thiers, "the body now reposes, and where it was soon to be rejoined by his companion in glory, the illustrious and virtuous Vauban, where he was destined to be joined one day by the author of the great things we are here relating; where he will certainly remain, surrounded by this august company, throughout the ages which Heaven may reserve for France."

How rash this prophecy of the illustrious historian, all past history may testify. (See also Alison's History of Europe, and Sir Thomas Browne on Urn Burial.)

[1] How suggestive are the following remarks of M. de Saulcy on the rock-tombs of the valley of Hinnom!—"The immense necropolis, traces of which are to be met with at every step in the valley, dates from the period when the Jebusites were masters of the country. After them the Israelites deposited the remains of their fathers in the same grottoes; and the same tombs, after having become at a still later period those of the Christians who had obtained possession of the Holy City, have, since the destruction of the Latin kingdom of Jerusalem, ceased to change both masters and occupants. Even the scattered bones are no more found in them; and from the city of the dead the dead alone have disappeared, while the abodes are still entire."—De Saulcy's Journey Round the Dead Sea, ii. 253.

these tribes of men as among us. They briefly anticipate the usual course of time—a little sooner verifying the inspired words, "Dust thou art, and unto dust thou shalt return."

There remain now only one or two other observations to complete our history of the revolutions of mineral matter.

Notwithstanding the constant return of plant and animal to the parent earth, all the mineral matter they contain does not remain where they are deposited. Rains and rivers daily remove from the soil a portion of the materials which are so essential to the perpetuation of animal and vegetable forms, and transport them to the sea. Thus the natural store of mineral food becomes daily smaller, and the land, in consequence, less fitted for the growth of plants.

But for this contingency also there is a provision. The solid rocks which compose the crust of the earth contain all these essential forms of inorganic matter in minute proportion. As these rocks crumble and mingle with the soil, they yield constant small supplies of each ingredient—of phosphoric acid, lime, magnesia, &c. These the springs which trickle through the rocks, from above or beneath, dissolve and diffuse wherever they go. Thus, in many localities, a moderate supply is day by day brought by evaporation of the soil water to the surface-soil, to replace that which, by natural causes, is constantly removed. And the great seas help in this work of restoration. They heave their lofty waves into the air and break in foam, that the rough wind may take up and bear back again to the land a portion of the salty spoils with which the rivers are ever enriching them. The weeds of the sea cast upon the shore, when dug into the soil by the careful farmer, restore nitrogen and valuable mineral matters once brought down by the rivers and apparently lost for ever in the deep. So also the fish withdrawn from the sea; and the guano which is brought from Peru and other hot regions, the solid excrement and carcasses of millions of fish-eating birds, and of seals and other marine animals—this guano brings back to the soil of England maybe the very phosphorus and nitrogen which it lost a decade or a century ago!

And then, lest these small daily restorations should not succeed in perpetually maintaining the necessary richness of the soil in mineral plant-food, slow but vast processes of change are in constant operation; and sometimes periods of

convulsion come at last to their aid. Great physical revolutions from time to time intervene. Now all at once, and now by slow degrees, the bottom of the sea becomes dry. Land and water change places, as they have often done during the geological history of the globe. And after each change, new races of plants forthwith begin to take up what rivers and rains had carried down into former sea-beds. The same mineral matter begins to play over again the same part as before, in the constant succession of animal and vegetable life! In this we see another long cycle through which certain ingredients of the solid earth are ever slowly moving.

Thus all the varieties of matter which are essential to the existence of living forms are in a constant state of circulation. Each has its appointed round of duty, at one point or other of which it is sure to be found. And while the motions of all the wheels are prescribed, and a restless activity imposed on every particle of matter, all contingencies are guarded against which might interfere with the final accomplishment of the one simple design.

How profound, yet how interesting and intelligible, is all this! How instructive the lessons it reads us! Thus—

1°. On how small a quantity of matter, for example, does it show us that all life depends. And no more material is used than is actually required, and only some fourteen kinds of elementary matter out of the sixty-six sorts of which our world is made up. Still the amount of matter in circulation, though relatively small when compared with the whole earth, is large when viewed by itself. Thus the daily consumption in food of the one element nitrogen by the whole population of the globe can scarcely be less than 135 tons, while the carbon will be twenty times as much. Over and over again, as the modeller fashions and refashions his clay, plant and animal are formed out of the same material. Over and over again it is transformed in the earth and in the air, as soon as it has been liberated for a time from the domain and dominion of life. Nature, in the words of Pope—

> "Builds life on death, on change duration founds,
> And bids the eternal wheels to know their rounds."

In the face of this clear knowledge, how crude, how untrue to nature, how irrational, how misleading are the views which

some have promulgated with regard to the final resurrection of man! As if the same matter which forms our body, when we are laid in the grave, and which, after a brief residence there, makes its way, through some nutritive plant, into the body of another man, and forms part of his body still when *he* is buried—as if this matter, which is neither his nor mine, has already "been slave to thousands," and may be buried with ten thousand bodies more, before the resurrection comes—as if this very matter were meant to form the clothing of the disembodied spirit, when, in visible form and sensible identity, it shall be raised on the day when "small and great" appear before the dread tribunal!

The words of the passage, "It is sown a natural body, it is raised a spiritual body;" and of this one, "The dead shall be raised incorruptible;"—these alone should be sufficient to deter the theological expositor from propounding ideas so gross in regard to the changes we are to undergo at that mysterious time. That which is formed of matter, *such as circulates in living beings now*, can neither be a spiritual body, nor free from the changes which are commonly implied by the word corruption.

2°. Again, the moral lesson is not unimportant which this steady but unceasing movement of the material particles of living bodies holds up to us. No stoppage long hinders it. No delay diverts its attention or causes it to forget its duty. Like the stone which we suspend in the air, it is ready to drop the instant the cord snaps by which it is upheld. Is all senseless matter to be thus perpetually labouring—and are we intelligent beings to idle away a precious but limited life? To work while we live—to take as large and as useful a part as possible in the great system of nature—is one of the moral lessons which the chemist reads in the movements, so plain to him, in apparently dead rocks and earth and air, not less than in the lifeless bodies of the animal and the plant.

3°. But they teach him also to work steadily and with a view to a definite and useful end. In contemplating the moving wheels I have one after another introduced to my readers, they must have felt inclined to stop and ask respecting each, "Why does this wheel turn? Why its unceasing restlessness? What purpose is effected, or is intended to be effected, by its endless revolution?" Generally the answer

is, that the maintenance of life, animal and vegetable, depends, as in a complicated piece of mechanism, upon the perpetual movement of all the wheels at once. In detail, the special answer is, that the turning of each wheel determines the comfortable discharge of one or more of the necessary functions of animal and vegetable life.

When, for example, the plant seems only to be amusing itself in forming starch and vegetable fat from carbonic acid and water, and the animal, in merely undoing what the plant has done—reconverting the starch and fat again into carbonic acid gas and water—an unseen effect is being produced at the same time, which is indispensably necessary to the continuance of animal life, as it is now constituted. The change which the starch and fat undergo in the animal body—as well as the final change which the gluten consumed by the animal undergoes—is a kind of burning. Part of the energy liberated by this burning is employed in doing work inside and outside the body, while part is used in the form of heat to keep the body warm; the necessity of such internal warmth to the maintenance of animal life is familiar to every one. This wise purpose, therefore, is served by the way, as it were, while the little wheel is turning by which carbonic acid and water alternately disappear in starch and fat, and alternately appear again in their gaseous and liquid forms. And so, were we curiously to inquire what physiological or other effects are produced during the turning of any other of our wheels, either great or small, we should see good coming out of each—a beneficent provision for the comfort of living animals, or for the healthy growth of vegetable forms, accompanying the sensible and chemical results of each revolution. In this the chemist reads the lesson that his ever-moving activity should have reference to a definite and good end.

4°. It is especially beautiful, as well as interesting, to see how clearly the consideration above presented exhibits the plant as the servant of the animal. Man placed upon the earth, without the previous existence of the plant, were utterly helpless. He could not live either upon earth or upon air, and yet his body requires a constant supply of the elements contained in both. It is the plant which selects, collects, and binds together these indigestible materials, manufacturing them into food for man and other animals. And these only

throw back again to their toiling slaves the waste or dead materials which they cannot further use, to be worked up by them anew into palatable and nutritious food. In this aspect, the plant appears only as the appointed bond-servant of the animal; and yet, how willing, how beautiful, how interesting a slave it is! It works unceasingly, yet it is self-tasked. It toils itself to death, yet, punctually as spring comes round, it rises again in a new life—young, beautiful, and willing as ever, rejoicing to renew its destined toil. There is in it none of the bitterness of human slavery to render the task unsweet. In this, too, there is a lesson for us.

5°. And it is not the least striking of the reflections to which this subject leads us, that an alteration in the natural constitution of things of so small a kind as to be inappreciable to our senses, would at once insure the certain extinction of animal and vegetable life. Let the All-powerful order that the minute proportion of carbonic acid in the atmosphere should be removed, and in a single hour vegetation would stagnate—in a single week, probably, the face of our fields and forests would be changed, and before many months all the green things of the earth would be dying or dead! And yet the human organs would perceive no change in the nature of the atmosphere, and the mass of mankind would first wonder at the fatal plague which had so suddenly stricken all vegetable forms, and after a brief period of stupefied and undefined dread, they, too, would perish as the plants for want of sustenance.

6°. This thought again leads us to the contemplation of those purely mechanical motions in which the heavenly bodies continually exercise themselves, without, as a consequence, undergoing any sensible chemical change of matter. On first becoming acquainted with the chemical revolutions of matter above described, we might be inclined—indeed it is a very natural first-sight question—to ask, What have these earthy revolutions which concern us so much—what have they in common with the majestic movements of satellites and planets in their orbits, and with that of systems in the ethereal space? What part do these lesser revolutions—annual many of them, like that of the earth round the sun—what part do they play in the system of the universe? The humbling answer is, that they take no sensible part in them at all.

The supposition of an insensible removal of the carbonic acid of the atmosphere, and a consideration of its consequences, show that the existence of life, either vegetable or animal, is not a necessary condition of things even on our globe. With an atmosphere so changed, the earth might roll on in its place in the solar system—its attendant moon still encircling it—for countless ages, without the change deranging, or even altering in any degree, the most insignificant phenomenon which is nightly seen in the starry heavens. Earthly life, therefore, has no share in the general system of the universe. It is a little episode, so to speak, in the great poem of creation. The Deity willed that this corner of His vast work should be the theatre of new displays of wisdom, of consummate contrivance, of a wonderful fitting-in of means to the accomplishment of beneficent ends, and at last the seat of an intellectual being, with capacity to study and comprehend and admire His works—to praise, and love, and serve Him. It is solely on this seemingly separate act of His will that we depend "for life, and breath, and all things."

And in thinking over this insignificance of man, and all his contemporary forms of life, how awful does it appear, that, in the event of a necessity arising, all this life could be stopped at once—by the simple turning of a screw, as it were—and that the disappearance of all our race would, to the physical universe, be of as little moment as the crushing of the tiny insects, to which all the world they know is but a drop of water! May the mere conception of such a catastrophe urge upon us the paramount duty of rendering worthy of survival that spiritual part of our being which no merely physical power can destroy!—This is the crowning lesson of all.

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